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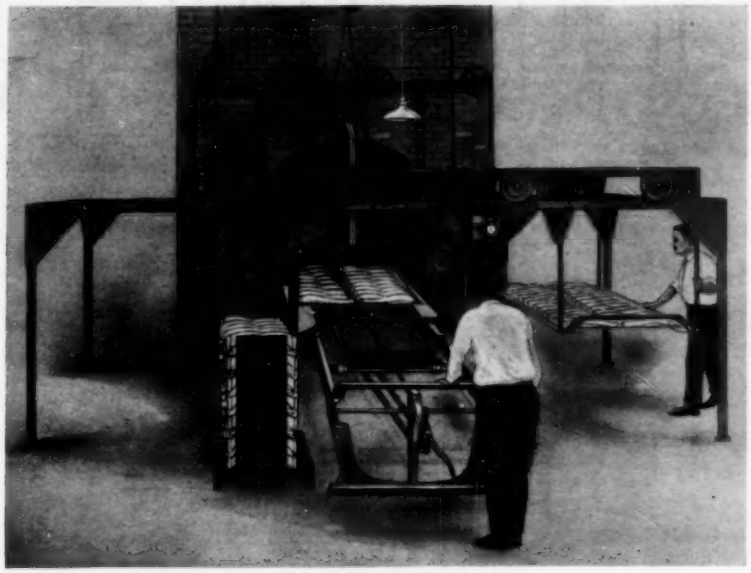

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Vol. 7 **February, 1924** **No. 2**

ORIGINAL PAPERS

THE BONDING EFFECT OF BALL CLAYS IN FIRED BODIES[1]

BY H. H. SORTWELL

ABSTRACT

Seven American and fourteen English ball clays were compared in regard to bonding effect, (*a*) after burning, in a composition containing no fluxes, at cones 5, 8, 10 and 12; (*b*) in a semi-porcelain body burned to cone 8; and (*c*) in a vitreous china body burned to cone 11. The English clays developed greater strength in the absence of fluxes. The semi-porcelain and vitreous china bodies containing the imported clays were in general of greater strength than those bodies in which the domestic clays were used, but most of the bodies containing American clays were of good transverse strength.

Introduction

Ball clay, because of its property of burning to a strong, dense structure at temperatures used in maturing chinaware, imparts strength to the product in addition to that produced through the action of fluxes. Since the mechanical strength of this type of ware is of great importance, it is desirable to know the relative effects of various ball clays, and the present investigation was undertaken to obtain this data.

This investigation is a continuation of the work reported in the Bureau of Standards, *Technologic Paper* No. 227, which deals with the physical characteristics and the drying and burning behavior of ball clays. The clays used in this study are a part of the same shipments used in the previous investigation. The data in this report are, therefore, compara-

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce. Received Dec. 1, 1923.

ble with those given in the *Technologic Paper* mentioned and the moduli of rupture of the clays in the dry state, as given, are quoted from that paper.

Procedure

The seven American and fourteen English ball clays used in the investigation were compared with regard to bonding effect in burned bodies in: (*a*) A composition containing no fluxes and burned to cones 5, 8, 10 and 12; (*b*) A semi-porcelain body burned to cone 8; and (*c*) A vitreous body burned to cone 11. Orton pyrometric cones were used in this work.

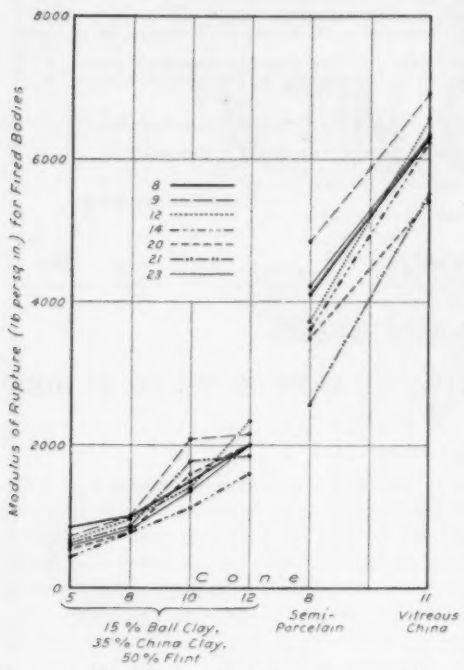

FIG. 1.—Transverse strength of compositions containing American ball clays.

The moisture content of the clays was determined so that comparisons could be made on the basis of the dry material. Each of the mixtures was ground in a ball mill two hours, filter-pressed, wedged, and pressed into bars 6 by 1 by 1 inches. Fifteen bars were made from each batch for each firing treatment.

For the comparison of the bonding effect of the clays in the absence of fluxes, the following composition was used with each clay: 50% flint, 35% English china clay, 15% ball clay.

Specimens of these compositions were fired at cones 5, 8, 10 and 12.

The semi-porcelain and vitreous china compositions used were:

	Semi-porcelain, per cent		Vitreous china, per cent
Ball clay	15	Ball clay	7½
Florida kaolin	8	Florida kaolin	8
English china clay	29	English china clay	29
Maine feldspar	14	Maine feldspar	18
Flint	34	Flint	36
		Whiting	1½

The semi-porcelain bodies were fired to cone 8 and the china bodies at cone 11.

All of the firing was done in a natural draft gas-fired laboratory kiln

of the Bureau. The kiln was heated to 1000°C in fifteen hours and was finished at the cone desired in about fifteen hours more. Cones were placed in each sagger and showed a variation of less than half a cone throughout the kiln for each burn. Specimens of each composition were distributed in various saggers throughout the kiln in order that possible variations in firing would affect equally all of the bodies.

The fired bars were broken over a five-inch span in an Olsen transverse testing machine of 1000 pounds capacity and the moduli of rupture computed. The amount of absorption of the semi-porcelain and china bodies was determined by the following method, which corresponds more closely to pottery practice than does the use of a vacuum.

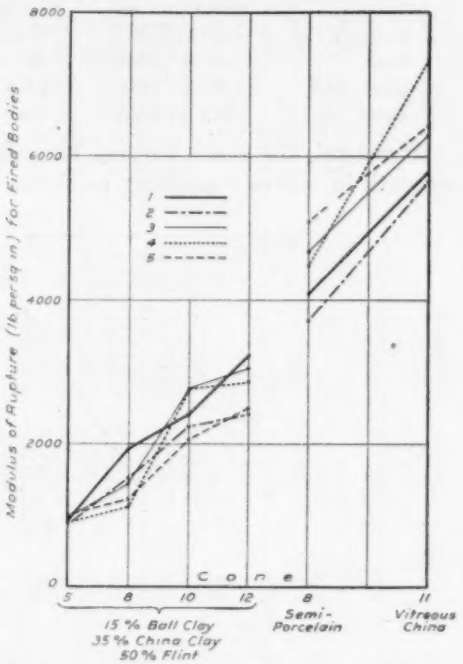

FIG. 2.—Transverse strength of compositions containing English ball clays.

The specimens were dried to constant weight at 110°C. They were then immersed in boiling water for five hours and allowed to cool to room temperature. When cool, the specimens were dried lightly with a damp cloth to remove excess water, and weighed in air. The per cent absorption was then calculated according to the following formula:

$$\text{Per cent absorption} = \frac{\text{wet weight} - \text{dry weight} \cdot 100}{\text{dry weight}}$$

Results

All of the numerical results given in Table I are the averages of five determinations. Fig. 1 shows graphically the transverse strength of the domestic clays tested in the fired compositions and corresponding data for the imported clays are given in Figs. 2, 3 and 4. The transverse strengths of the dried bodies are shown in Fig. 5.

Bodies Containing No Fluxes

A study of the strengths of fired compositions containing no feldspar indicates the differences in bonding power of the clays when no flux is

present. The following Table II shows clearly the comparison of the American and English clays:

TABLE II

	American clays, range in strength	Average	English clays, range in strength	Average
Cone 5	439 to 845	633	885 to 1333	1032
Cone 8	810 to 1004	891	1077 to 1926	1542
Cone 10	1121 to 2135	1574	1572 to 2905	2442
Cone 12	1620 to 2355	1999	2467 to 3360	2980

In general, the dense burning English ball clays develop much greater strength in bodies containing no fluxes than do the American ball clays which do not vitrify at pottery temperatures. Consequently, the former are more desirable for use in those compositions in which clays alone are relied upon to produce high strength.

From a comparison of the transverse strength of these bodies with those of the dried clay-flint mixtures it is apparent that the latter do not give a reliable indication of the bonding effect after firing.

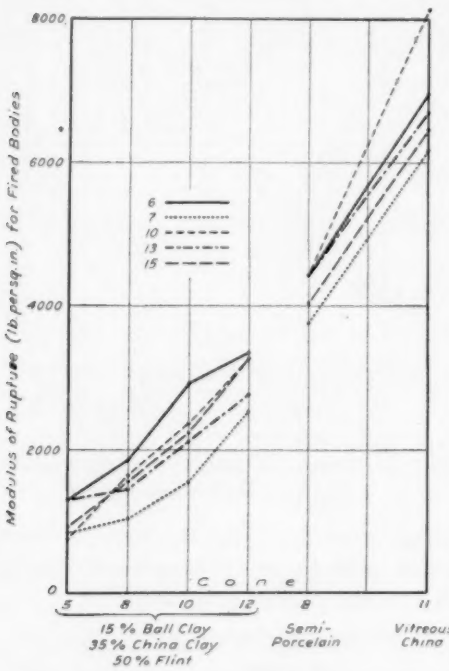

FIG. 3.—Transverse strength of compositions containing English ball clays.

Semi-Porcelain Bodies

The moduli of rupture of the semi-porcelain bodies varied from 3500 to 5000 pounds per square inch, with the exception of body No. 21, which developed a strength of 2560 pounds per square inch. From these data it is evident that ball clays greatly affect the strength of this type of body when burned.

The difference in bonding effect between the domestic and imported clays was not so pronounced in the semi-porcelain body containing 14% of feldspar as in the bodies containing no fluxes. Several of the semi-porcelains made with American clays were of good strength, the moduli of rupture of the bodies, with one exception, varying from 3500 to 4854 pounds per square inch, and averaging 4034 pounds. The same type of body, using English ball clays, ranged from 3783 to 5055 pounds per square inch, and averaged 4312 pounds.

TABLE I

RESULTS OF MODULUS OF RUPTURE AND ABSORPTION DETERMINATIONS

Lab. No.	Name of clay	Modulus of rupture dried 50 clay—50 flint	Modulus of rupture Cone 5	Modulus of rupture Cone 8	Modulus of rupture Cone 10	Modulus of rupture Cone 12	Semi-porcelain Modulus of rupture Cone 8	Semi-porcelain Per cent absorption Cone 8	Vitreous china Modulus of rupture Cone 11	Vitreous china Per cent absorption Cone 11
1	English ball clay No. 1	376	958	1926	2473	3271	4108	11.8	5869	2.0
2	English ball clay No. 2	375	937	1527	2300	2467	3783	11.3	5694	2.9
3	English ball clay No. 12	568	1085	1424	2730	3066	4687	9.1	6385	1.3
4	Whiteway ball clay	446	911	1178	2744	2898	4470	9.5	7411	.5
5	English ball clay No. 90	441	1059	1256	2095	2533	5055	8.8	6445	2.2
6	Pikes ball clay	381	1331	1872	2905	3360	4387	7.2	7023	.9
7	Superior ball clay	563	885	1077	1572	2561	3788	8.9	6188	1.6
8	Kentucky ball clay No. 4	372	845	999	1513	1982	4118	9.9	6333	1.7
9	Tennessee ball clay No. 5	478	702	947	2135	2104	4854	8.4	6922	1.2
10	No. 25 blue ball clay	403	868	1673	2375	3297	4361	9.5	8114	.9
12	Tennessee ball clay No. 11	293	682	1004	1447	2355	3748	12.1	6563	.6
13	Dorset ball clay	492	1333	1502	2184	2844	4396	10.5	6734	.9
14	Kentucky ball clay No. 10	223	439	844	1121	1620	3671	11.6	6226	1.4
15	English ball clay No. 11	396	1002	1668	2290	3332	4031	10.0	6505	.9
16	Fayles ball clay	347	1169	1664	2798	2871	4207	9.5	6545	.8
17	Grindley ball clay	427	913	1320	2518	3207	4568	9.3	6072	1.4
18	Great Beam ball clay	454	1011	1649	2682	3207	4335	10.9	5950	1.4
20	Tennessee ball clay No. 3	327	554	811	1576	1992	3500	11.9	5443	3.9
21	Tennessee ball clay No. 10	...	587	825	1785	1893	2564	13.8	5583	1.7
22	M. & M. English ball clay	384	994	1857	2558	2800	4194	10.7	5502	3.0
23	Tennessee ball clay No. 9	...	625	810	1440	2048	4212	10.6	6430	2.9

It is interesting to note, in this connection, that the bonding effect of the ball clays in the semi-porcelain bodies appears in some instances to be related to the bonding effect in bodies containing no fluxes. However, this relation is not dependable and the bonding power of a ball clay should, therefore, be studied in the type of body in which it is to be used.

The effect of the ball clay on the absorption is shown in Table I. The semi-porcelains varied from 7.2% in the case of No. 6, an English clay, to 13.8% in the case of No. 21, the clay which developed the least strength of all of the bodies at cone 8. However, a small part of this difference must be attributed to slight variations in firing.

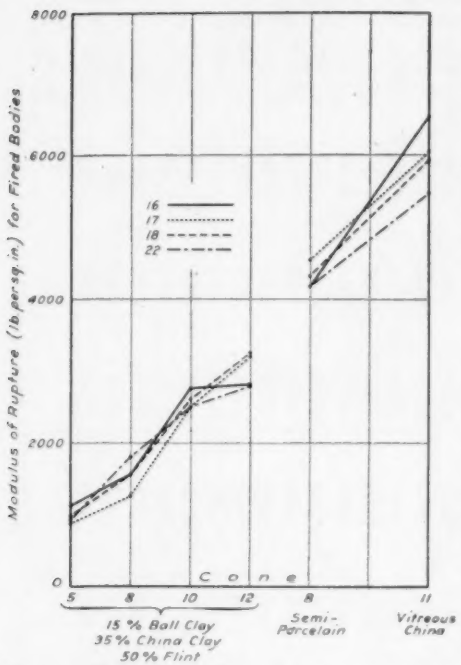

FIG. 4.—Transverse strength of compositions containing English ball clays.

Vitreous Bodies

In regard to the relative values for domestic and foreign clays, the results on the vitreous china compositions containing only $7\frac{1}{2}\%$ of ball clay were similar to those for the semi-porcelains. The bodies containing domestic ball clays had moduli of rupture ranging from 5443 to 6922 pounds per square inch, while those with imported clays ranged from 5502 to 8114 pounds per square inch. The averages were 6214 for the domestic clays and 6460 for the English.

A special body of this type, containing English china clay instead of ball clay, was prepared and burned. This body developed a modulus of rupture of 5875 pounds per square inch, which was higher than that of several of the bodies containing ball clays. This might indicate that some of the ball clays had been fired higher than the temperature at which their maximum strength is developed.

General

Neither the strength in the dried state nor the strength in bodies containing no fluxes gives dependable indication of the bonding effect to be expected in commercial semi-porcelain or vitreous compositions. For a reliable criterion of the strength of a body containing a given clay, the

clay should be tested in the same composition and under same conditions of burning which are to be used in actual practice.

The difference in strength of the semi-porcelains and vitreous china composition bodies differing only in ball clay shows the important in-

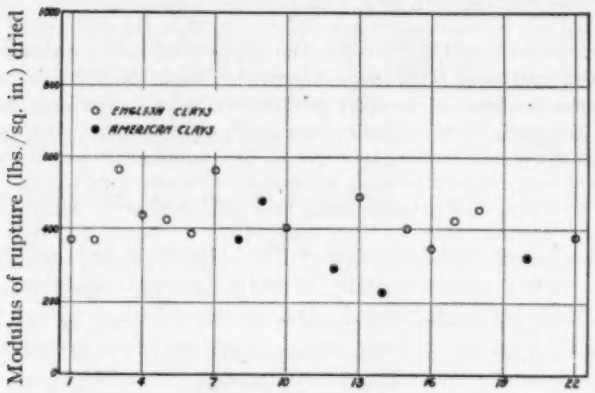

FIG. 5.—Strengths of American and English ball clays in the dried state.

fluence of the ball clay on the strength of the product and proves the value of a test of this kind in the selection of materials when developing compositions of high strength.

Summary

Transverse strength determinations showed the fourteen English ball clays to have greater bonding effect, in general, than the seven American clays included in the work when used in a composition containing no fluxes.

The average strength of the semi-porcelain and vitreous china bodies containing the English ball clays was slightly higher than the same bodies containing the domestic ball clays. A number of the domestic clays, however, contributed greater strength to these bodies than the lowest imported clays, with results that were very satisfactory. Only three of the English clays gave extremely high strengths to the semi-porcelain and vitreous bodies.

Neither the strength of a clay in the dried state nor in a composition containing no active fluxes gave a reliable criterion of the strength to be contributed by it to a commercial composition.

The ball clay has an important effect on the mechanical strength of fired bodies, which should be taken into consideration in developing compositions of high strength.

U. S. BUREAU OF STANDARDS
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HANDLING AND STORING RAW MATERIALS TO PRODUCE UNIFORMITY IN A BODY[1]

By Robert Twells, Jr.

ABSTRACT

Ceramic raw materials are usually heterogeneous mixtures rather than pure substances. Variations in composition are likely to occur in the materials as received at the plant both within individual carloads and between successive carloads of the same material. Such variations often cause trouble in plants making vitreous porcelain. The article describes ways of avoiding trouble, (*a*) by rendering each carload homogeneous as it is stored, (*b*) by withdrawing a material from several lots simultaneously to make the body; in withdrawing from several lots simultaneously, the process should preferably be continuous, one lot being finished as a new one is started, (*d*) and by keeping accurate records of the materials going into each production batch of body.

As a rule the raw materials used in the ceramic industries are not pure substances. They consist usually of heterogeneous mixtures of minerals in different states of aggregation. Due to this inherent nature wide variations are likely to occur in their chemical and physical properties. These differences are relatively unimportant in some branches of ceramic work, but in the manufacture of vitreous ware, particularly high-fire vitreous ware, they are very important. Consequently in these industries a great deal of trouble and expense in handling is justified if it tends to insure uniformity in the raw materials.

If the materials are received at a plant in carload lots, variations usually occur in two ways:

(1) The first type is that found within an individual car. A sample from one part of a car may differ widely in chemical analysis and physical tests from another sample taken near by. Even a carefully selected average sample of an entire carload is not necessarily a safe guide for its use in production until the whole is rendered homogeneous. This can only be made certain by mixing the material thoroughly as it is being unloaded and stored. The amount of mixing necessary depends entirely upon the sensitiveness of the body to changes in the raw materials. For practical purposes it is usually sufficient to unload both ends of a car simultaneously and dump the materials together in a bin, preferably in the form of a cone. Finely ground materials in bulk are particularly adapted to this way of unloading as they are relatively well mixed as received, and when dumped in a pile are inclined to flow in all directions. Lump materials such as clays should also be unloaded simultaneously from both ends of the car but should be pulverized in a crusher before they are stored to prevent segregation of the different sizes. With a particularly sensitive body it might even be desirable to pass each material through a mechanical mixer before storing it in a bin. In any case each opportunity should be

[1] A contribution from the Research Laboratories of the Champion Porcelain Company and the Jeffery-Dewitt Insulator Company. Received Dec. 19, 1923.

seized to mix a material as much as possible as it is being handled in order to make each carload as nearly homogeneous as practical.

(2) A second type of variation is that found between successive carloads of the same material. For example, a carefully taken average sample from one car usually differs considerably from a similar sample out of the next shipment. The problem in this case is to eliminate the differences between cars entirely or to lessen the danger of a change by making it occur more gradually. In contending with this type of variation there are several rules which, when observed, tend to eliminate possible difficulties:

(*a*) Each carload of material should be rendered homogeneous.

(*b*) As many carloads as practical of a material should be withdrawn simultaneously to make the body. This tends to counteract differences between individual carloads.

(*c*) As far as possible when drawing from several cars of a material it should be arranged that all the cars would not be finished at once, but one would be finished as a new one is started. In other words the system of storing and withdrawing should be continuous.

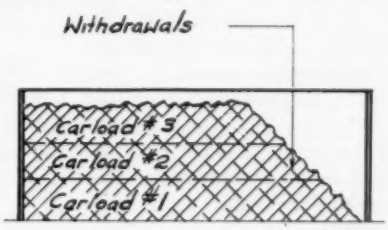


FIG. 1.—Sketch showing the method of storing three cars of a material in a bin and the method of withdrawal to produce a mixture of the three.

(*d*) It is often not convenient to store an individual carload of a material separately. When several carloads are dumped into one bin or pile the above rules should still be followed.

(*e*) Careful records should be kept of the materials going into each production batch of a body. Any changes in raw materials can then be traced through production and the effects noted. Trouble can often be avoided by knowing just at what point a change in the body is to be expected. Operating conditions can then be altered to correct for the differences.

At the Champion Porcelain Company the above principles have been observed for some time in handling various quantities of new materials and also large amounts of scrap materials, kept for reuse. The particular methods followed may be of interest. The storage bins now in use each hold from two to three carloads depending on the size of the cars and the kind of material. The first carload (Fig. 1) is dumped into a bin roughly in the form of a cone or pyramid. It is then carefully leveled off to a uniform depth over the whole bin. A second car is likewise dumped on top of the first and leveled up in a similar manner. If the bin will hold a third car, it also is put in and leveled up like the first two. The result

is that the bin contains two or three horizontal strata of material, each stratum being practically homogeneous. The material is withdrawn nearly vertically from one end of the bin giving practically a uniform mixture of all the cars for use in the body. This method eliminates the effects of variations between individual carloads but does not eliminate the possible result of a change from one bin to the next. To make the system continuous a slightly different plan has been used: One or more cars of a material are stored to a bin as described above. Three such bins of material are needed (Fig. 2.) One of the bins is used in the body until it is one-third empty; then a second bin is started and the two used in equal proportions until the first is two-thirds empty and the second one-third empty. The third bin is next started and the three used in equal parts until the first bin is empty, the second one-third full and the third two-thirds full. The first bin is then refilled and the three used in equal proportions, as before, each bin being refilled in turn as it becomes empty. This method can be extended to the mixing of as many separate bins as desired, but three are about its limit of practicability.

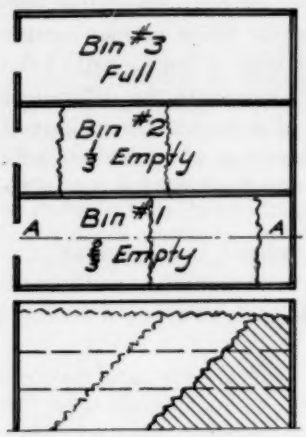
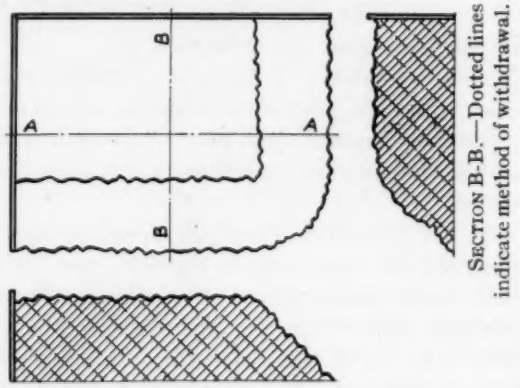


FIG. 2.—Sketch showing a continuous method of storing and withdrawing a material to produce a mixture of three bins, each bin holding three cars when full. The material is taken from the bins in equal proportions, and the bins are refilled as they are emptied.

For materials requiring great care it is desirable to mix as much as practical together in one large pile. For this purpose another plan has been successfully used in storing and mixing quantities up to a thousand tons. The pile (Fig. 3) is started at one end of an area and the material deposited in thin semi-vertical layers parallel to the first portion of the pile laid down. The pile can be extended in this way to any length desired.



SECTION A-A.—Dotted lines indicate method of laying pile.

FIG. 3.—Sketch showing a method of storing a great many car loads of a material and the manner of withdrawal to produce a mixture of them all.

In withdrawing the material for use thin strips are removed from the entire face of the pile. These strips are taken at right angles to the original strata of the pile as laid down. Each layer withdrawn thus, contains a small amount of each stratum in the pile. This method as described is not continuous in operation. It can be made so by the continued deposition of new strata at one end of the pile, and the withdrawal of the material at the other end and a side at about a 60° angle with the original layers.

Some no doubt will feel that these precautions in handling raw materials are rather far-fetched and unnecessary. Whether or not similar methods would be advantageous in other ceramic industries is a question to be decided by the individual requirements. The writer believes that they are applicable generally in plants making products having close limits as to dimensions or using a body with a narrow firing range. Their adoption here was due to hard knocks previously received, and the results to date have been well worth the trouble. The present tendency at this plant is towards still greater care. Larger and larger amounts of material are being stored and increasing pains are being taken to render each practically homogeneous.

THE ELECTRICAL CONDUCTIVITY OF SODIUM CHLORIDE IN MOLTEN GLASS[1]

By Willard J. Sutton[2] and Alexander Silverman

ABSTRACT

Precipitation of collodial suspensions in glass by dissolved salts leads to the assumption that they ionize. In this investigation the conductivity of glass alone and with dissolved salts confirms the theory. A special cell has been devised for conductivity work in glass at high temperatures. This is the first study of the electrical conductivity of salts in vitreous media.

Introduction

This investigation was undertaken primarily to show that sodium chloride ionizes in molten glass as it does in aqueous solution, and also when the pure salt is heated to temperatures at or above its melting point. This was prompted by the tendency of chlorides and sulfates, dissolved in molten opal glasses, to precipitate the colloidal material, and produce alabaster glass through the destruction of opalescence.[3] The electrical conductivity of a simple soda-lime glass was first determined at various temperatures above the softening point, and then the conductivity was determined when the glass contained various percentages of sodium chloride.

There is but little data at present to show the molecular constitution of a glass. Conductivity measurements of molten salts have done much to show their degree of ionization, and molecular state. Since glass is but a supercooled liquid mixture of complex salts, conductivity data will most probably do much to solve this difficult problem of structure.

Historical Review

Considerable data have been obtained on the electrical conductivity of solid glasses of different types,[4] but only a little information is available for molten glass. This is due to the greater difficulty of measuring the conductivity of a molten glass, and because much of the work done on solid glasses was a study of electric insulators.

Glass has always been regarded as an electric insulator at room temperature, but as early as 1854 it was shown to be a conductor when heated to 100°C.[5] Warburg,[6] using voltages as high as sixty, and passing the

[1] Contribution from the Department of Chemistry, University of Pittsburgh.

[2] Thesis submitted to the Faculty of the Graduate School, University of Pittsburgh, in partial fulfillment of requirements for the Ph.D. degree. Received Dec. 21, 1923.

[3] A. Silverman, *Jour. Amer. Ceram. Soc.*, **1**, 251 (1918).

[4] Clark, *Glass Ind.*, **2**, 221 (1921); "Smithsonian Physical Tables," 6th ed., 282 (1918); Gray and Dobbie, *Proc. Roy. Soc. London*, **67**, 197–200 (1900).

[5] Buff, *Liebig Ann.*, **90**, 257 (1854); Beetz, *ibid.*, **92**, 452 (1854).

[6] *Ann. Physik.*, **21**, 622 (1884).

current through a glass tube by means of mercury electrodes, found that the resistance of the glass increased quite rapidly, so that the current fell to a thousandth of its original value. With such high voltages, the resistance could not be due to polarization, and Warburg found sodium from the glass in the cathode mercury. A white, poorly conducting layer was formed in the glass at the anode surface. By using sodium amalgam as an anode, the current flowed through the glass without change or the formation of a poorly conducting layer, the sodium in the glass being constantly replaced as it was removed by electrolysis. By using lithium amalgam, Tegetmeier[1] showed that lithium could displace the sodium and be passed through the glass. The progress of the lithium into the glass could be measured as it formed a white opaque layer. Kraus and Darby[2] have shown that this can take place slowly without influence of the electric current, and that the white appearance was due to microscopic cracks, which in some cases caused the glass to disintegrate.

Warburg (*loc. cit.*), LeBlanc and Kerschbaum[3] and others have shown that the conduction of electricity through a glass obeys Faraday's law, but that only the positive alkali metal ions take part in the conduction. This condition, where solids conduct electricity, obeying Faraday's law, and where the positive ions carry all the current while the negative ions form a mechanically rigid framework, has been observed with silver chloride, silver bromide, silver iodide, silver sulfide (above 179°C), and cuprous sulfide. In lead chloride and fluoride the negative ions carry the current.[4]

By passing a current through glass plates, LeBlanc and Kerschbaum produced poorly conducting layers at the anode surface, and on grinding these off, the glass conducted as well as before. A Thuringian glass containing approximately 9% of sodium was used, and when the current was reversed the conductivity would increase again almost to its original value. These investigators reasoned that the negative ions must have a composition $2(SiO_3 + xSiO_2)$ which should decompose to form $2(x + 1)SiO_2 + O_2$ in the poorly conducting layer. At the temperature used (250–300°C) no gas was liberated, but on heating to higher temperatures oxygen was given off, chemically equivalent to the sodium found in the cathode mercury within the limits of experimental error.

By measuring the percentage of the sodium that can be removed from a glass by electrolysis, the fractional part which ionizes can be determined. LeBlanc and Kerschbaum found their glass to be 80% ionized. Kraus and Darby used a glass containing 16.90% Na_2O, 2.35% Fe_2O_3 and Al_2O_3, and 11.24% CaO and PbO. Data obtained on this glass are as follows:

[1] *Ann. Physik.*, **41,** 18 (1890).
[2] *Jour. Amer. Chem. Soc.*, **44,** 2785 (1922).
[3] *Z. physik. Chem.*, **72,** 468 (1910).
[4] Tubandt, *Z. anorg. allgem. Chem.*, **115,** 105–126 (1921).

TABLE I

Temperature.....	278°C	295°	323°	343°
Ionization of sodium...	74.4%	76.8%	79.4%	81.0%
Speed of sodium ion (cm./sec./v.).....	4.52×10^{-8}	1.46×10^{-7}	3.26×10^{-7}	5.9×10^{-6}
Resistance, ohms.....	72,800	35,000	14,200	6,600

Heydweiller and Kopferman[1] and Kraus and Darby[2] have carried out the electrolysis of glass using molten salts as anodes. Lithium, sodium, potassium and silver can be readily introduced into the glass in this way, but the same change takes place slowly at high temperatures without the influence of the electric current. When sodium is displaced by other metals, the glass tends to crack on cooling. Copper, zinc, lead and other metals also enter glass when their molten salts are used as anodes, showing their entry by color effects, or disintegration. Silver had been found to be the best metal to replace sodium in glass, atom for atom; electrolytically. The speed of the ions could be measured by the moving boundary method, as the silver formed a light amber color at 250°C, which turned red or brown at higher temperatures.

When an ordinary soda lime glass is subjected to electrolysis at high temperatures, with concentrated sulfuric acid as an anode, the effect is similar to that mentioned when lithium amalgam was used.[3] The glass became opaque and white, and the current finally became greater than its original value. With Jena and lead glasses, however, a poorly conducting layer was formed.

Foussereau[4] has shown that a glass conducts better when tempered than when it is annealed. A certain lime glass decreased in conductivity 2.3 times on reheating and annealing. Gray and Dobbie (*loc. cit.*) determined the resistance of a potash lead glass at 130°C as $18{,}000 \times 10^{10}$ ohms. They found the resistance of a similar soda glass to be only 136×10^{10} ohms. Since the conduction is by the positive ions in solid glass, it is apparent that the specific conductivity is proportional to the absolute velocity of the ions present.

Porcelain is somewhat similar to a glass and at high temperatures it obeys Faraday's law. Haber[5] reported the electrolysis of an unglazed Royal Berlin crucible between electrodes of molten tin. This was carried on between temperatures of 330° to 1250°C and on analyzing the cathode tin he found sodium, potassium, aluminum, iron, calcium and magnesium to be deposited electrolytically. It was definitely shown that the relation

[1] *Ann. Physik.*, **32**, 327 (1913).
[2] *Loc. cit.*
[3] Speranskii, *Jour. Russ. Phys. Chem. Soc.*, **47**, 52–58 (1915).
[4] *Compt. rend.*, **96**, 785–787 (1883).
[5] *Z. anorg. Chem.*, **57**, 154–173 (1908).

between current strength and migration of metal ions held for hot porcelain, as it does for aqueous solutions. At the lower temperatures used, Haber believed the main silicate of porcelain, $Al_2(SiO_3)_3$, acts as solvent and the glassy silicates act as electrolytes. At about 1000°C the aluminum silicate also seemed to conduct. From this it would seem that only certain alkali silicates ionize at the temperatures of the experiments on solid glass (100–500°C), but that silicates of other metals dissociate at higher temperatures.

Silicates can be divided into two general classes, glassy and crystalline. Doelter[1] observed that glasses show no sharp bend at the melting point on conductivity-temperature curves, but that crystalline silicates show a marked change starting just below the melting point. When 200°C above or below the melting point, the conductivity of all the silicates studied was almost a linear function of the temperature. The temperature coefficient of solids was high, that of liquids was low. Doelter[2] concluded with many others, that the increase in conductivity with temperature is due mostly to increased mobility of the ions, and not to a great increase in ionization. Viscosity and elasticity may have some effect, especially the former, but there is no marked change in the conductivity of a glass at the melting point, where the viscosity is very great. Albite (sodium feldspar) formed one of the most viscous glasses, but it conducted best, and aluminum was found alloyed with the cathode.

The conductivity of many silicates was determined, using platinum electrodes in crucibles of a quartz-kaolin mixture. The results were too inaccurate, due to experimental difficulties, to give numerical data, but the general behavior was shown. Calcium metasilicate[3] ($CaSiO_3$) showed about the same conductivity with both the artificial product and the natural mineral (Wollastonite), giving no sharp change at the melting point. Calcium alumino-silicate [$2Ca\,SiO_3 . CaO . Al_2O_3$] shows a marked change at the melting point, indicating increased dissociation, and decreased viscosity.

Much work has been done on the electrical conductivity of molten salts,[4] and glass is but a mixture of salts. R. Lorenz and Kalmus,[5] used a capillary cell with good results. This cell consisted of two horizontal electrodes, separated by a capillary tube of glass or quartz. Such a cell could not be used for molten glass because of the difficulty of removing air bubbles from the viscous melt. U-tubes of porcelain were also employed

[1] *Monatsh.*, **28,** 1313–1380 (1908); **29,** 607–644 (1909).

[2] *Z. Elektrochem.*, **14,** 552–555 (1908).

[3] Doelter, *Zentr. Hydraul. Zemente*, **1,** 104–111 (1911).

[4] R. Lorenz, "Die Elektrolyse geschmolzener Salze." Wilhelm Knapp, Halle & S. (1908).

[5] *Z. physik. Chem.*, **59,** 17 (1907).

but these have the same objection as the capillary cells when used with molten glass.

Goodwin and Mailey[1] have determined the conductivity of molten lithium, sodium, potassium, and silver nitrates and silver chlorate, over long temperature ranges. The equivalent conductivity of mixtures of sodium and potassium nitrates was found to be about 3% less than that calculated by the law of mixtures. This indicates that these salts do not react and are probably highly ionized. If the deviation is not due to experimental error it would show less dissociation in mixtures with a common ion. In the case of silver chlorate and lithium nitrate, the conductivity was much below that calculated for the mixture. The equivalent conductivity of fused potassium nitrate, divided by the fluidity (reciprocal of viscosity), was found to be nearly a constant, gradually decreasing with increasing temperature. This behavior is common with most salts. From these facts, it would seem possible that sodium chloride in a soda-lime glass would give a lower conductivity than that calculated for the mixture, and this was found to be the case.

The following table gives a good comparison of the conductivity of fused salts with their conductivity in normal aqueous solutions.[2]

TABLE II

Salt	Temperature	Sp. condy., fused	N. sol. 18°C, sp. condy.	Equiv. condy. i°	Equiv. condy. 18°
$NaNO_3$	350°C	1.173	0.0660	52.87	105
KNO_3	350°	0.673	.0804	36.54	126
$AgNO_3$	350°	1.245	.0678	55.43	117
NaCl	850°	3.50	.0744	137.00	110
KCl	850°	2.30	.0982	117.00	131

Sandonnini[3] has also determined the electrical conductivity of molten salt mixtures. The values observed were always lower than those calculated for the mixtures, and the deviation was greatest for those pairs which formed compounds.

Experimental Work

Measuring Apparatus.—The electrical conductivity of the molten glass was measured by the improved method of Kohlrausch,[4] for electrolytes. A Vreeland oscillator operating on 110 volt d. c. was used giving an alternating current with a frequency of 1000. The arrangement of the apparatus is shown in Fig. 1. A known resistance and the re-

[1] *Phys. Rev.*, **25**, 469–489 (1908); **26**, 28–60 (1908).

[2] Goodwin, *Trans. Am. Electrochem. Soc.*, **21**, 105 (1912).

[3] *Atti. accad. Lincei*, **24** [1], 616–21 (1915); *Gazz. chim. ital.*, **501**, 289–321 (1920).

[4] Kohlrausch and Holborn, "Leitvermögen der Elektrolyte," Teubner, Leipzig (1898).

sistance of a conductivity cell were balanced in opposite arms of a Wheatstone bridge, the point of balance being determined by means of a sound minimum in a telephone receiver.

The bridge employed (Fig. 1-E) was of the usual drum-wound type, having ten turns of wire on a marble cylinder. The readings of the bridge wire could be estimated with great accuracy to one ten-thousandth of its total length. A 99,999 ohm resistance box (Fig. 1-B) with bifilar coils was used. Due to the large power factor of the larger coils of this type, resistance units higher than 100 ohms were not used. The resistance box was not calibrated, but it was checked by measuring the conductivity of aqueous solutions at room temperature. Checks could easily be made to 0.05% which is much below the error caused by other factors of the determination. A fairly sharp minimum in the telephones was maintained by balancing out the capacity of the cell by means of variable condensers (Fig. 1-A) connected in parallel across the resistance box. For this purpose a variable air condenser of about 0.0004 microfarad capacity, and two mica box condensers were employed. The latter had various convenient units from 0.001 to 0.5 microfarad with a total capacity of about 1.2 microfarads.

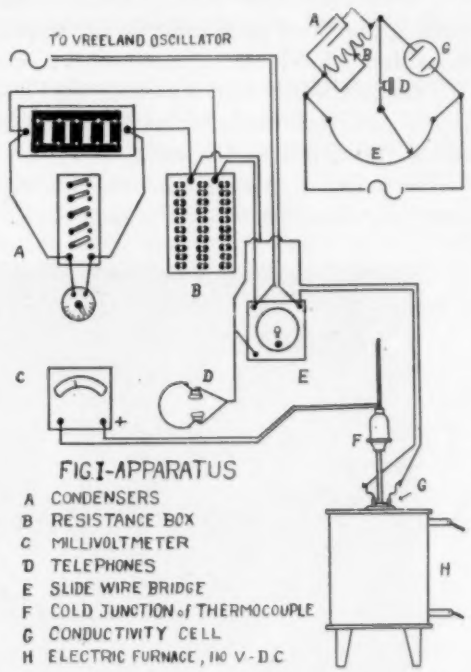


FIG.1-APPARATUS

A CONDENSERS
B RESISTANCE BOX
C MILLIVOLTMETER
D TELEPHONES
E SLIDE WIRE BRIDGE
F COLD JUNCTION of THERMOCOUPLE
G CONDUCTIVITY CELL
H ELECTRIC FURNACE, 110 V-D C

Furnace.—The conductivity cell was heated in a 110 v. d. c. vertical furnace (Fig. 1-H) having a granular carbon resistance element. An ordinary nichrome wire-wound furnace would have been more suitable if it had not been necessary to raise the temperature much above 1000°C to free the glass from bubbles. By carefully adjusting the rheostat the temperature could be kept constant to less than a degree, for at least a minute. Ordinarily it took less than fifteen seconds to balance the bridge and get the temperature reading. At 1000°C the change in specific conductivity of the glass was about 0.6% per degree, while at 800° it was about 1.0%.

Temperature Measurements.—A platinum—(90% platinum, 10% rhodium) thermocouple was used in all temperature measurements of the glass. The cold junction (Fig. 1-F) was kept in an iron jacket at the end of the porcelain protection tube, and its temperature was measured by a 200° thermometer inserted between the leads. The millivolt reading was taken on a Weston, model 322, pyro-millivoltmeter (Fig. 1-C).*

The thermocouple was calibrated under working conditions by the melting points of pure electrolytic copper covered with graphite (1083°), of sodium chloride (801°), and of pure zinc covered with graphite (419.4°). The furnace was heated about 50–100° above the melting point of the substance and then the thermocouple was carefully inserted to about two-thirds the depth of the melt.

For practical reasons the thermocouple was calibrated with a cold junction temperature of 30°C, and under working conditions the extreme

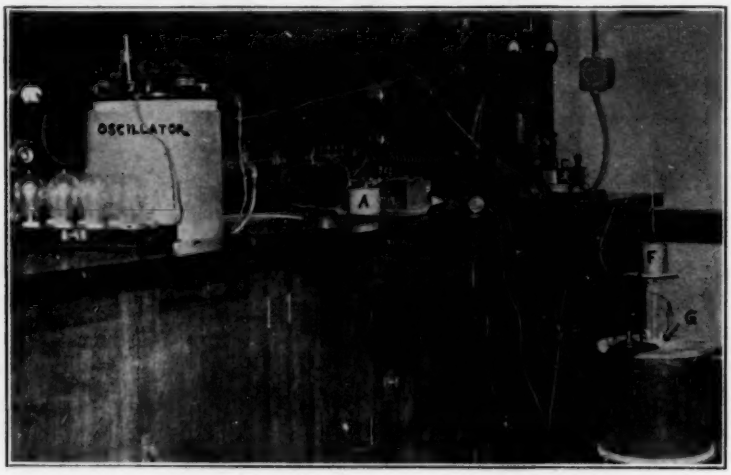


FIG. 1-*a*.

deviation was ±10°. For this type of couple the correction to be added to the temperature calculated from the millivolt reading is small.

The calibration was carried out according to directions given by the U. S. Bureau of Standards.[1]

Conductivity Cell.—(Fig. 1-G and Fig. 2.) By far the greatest difficulty in this work was to obtain a cell that would meet the necessary requirements. Briefly, these are as follows:

1. The material must be as nearly a non-conductor as possible at the high temperatures to which it is subjected.

[1] "Pyrometric Practice," Bur. Stand., *Tech. Paper* **170,** 54–55, 189–206, 234–239 (1921).

2. It must not shrink or soften at the temperature used, and must not contaminate the molten glass to any great extent.

3. The coefficient of expansion should be as small as possible to keep the temperature coefficient of the cell constant quite low.

4. The material must be plastic in its preparatory stage, to be molded into suitable shape and to hold the electrodes firmly.

5. The electrode metal should conduct well, should be chemically inert towards glass, have a high melting point, and if possible, low coefficients of expansion and resistance.

Several attempts were made to produce cells before a suitable type was obtained. The first attempt consisted of a special furnace cover molded of fire clay to hold two quartz insulating tubes, which converged in the center of a porcelain crucible set in the furnace chamber. Sheet platinum electrodes about 1 cm. square and 1 cm. apart were employed. The size and distance apart of the electrodes could easily be adjusted and a cell constant could be determined, but there was danger of bending the electrodes when placing apparatus in the furnace. It was also practically impossible to replace the electrodes in exactly the same position in the crucible after getting their resistance capacity. This could be avoided in a much larger crucible containing a large batch of glass, where the walls would not interfere with the "edge effect" of the conductivity between the electrodes. Larger crucibles, however, cannot be employed in the furnaces suitable for this work, due to lack of uniformity of temperature. The greatest objection was that the electrodes were not rigid enough to allow the bubbles to be removed by stirring.

The second attempt was similar to the first except that heavy nickel rods were used for electrodes, extending through heavy quartz insulating tubes. Here the electrodes were rigid and bubbles could be removed, but the "edge effect" would cause error if the same setting in the crucible were not reproduced after determining the cell constant. A series of experiments showed that it was not possible to reproduce exactly the electrode position and that considerable error might arise.

The third cell was like the second in principle, but more elaborate. A porcelain form was made which held the nickel rods and also served as container for the glass. Here the bubbles could be removed less readily than in the second type, but the electrodes were always in the same relative position. In both this and the preceding cell, however, there was considerable expansion of the nickel rods on heating. Nickel is a suitable electrode material if protected from oxidation, or if the bright metal is suddenly immersed in the molten glass. The rods could not be held tightly, due to their great expansion, and corrections could not easily be determined. The cell was abandoned after several determinations failed to give check results.

The final form of cell adopted for this work is shown in Fig. 2. Porcelain and platinum were chosen as the most suitable materials.

The porcelain was made from the best commercial grade of materials obtainable on the market. The quartz and feldspar were already finely ground, and by further grinding in a mortar and subsequent mixing with water, the clays could easily be brought to a fine state of division. The powdered materials were weighed, mixed dry, and then thoroughly mixed with water until a uniform plastic body was obtained. The composition was as follows:—

Ground quartz	34 parts by weight
Potash feldspar	16 parts by weight
Tennessee ball clay No. 3	20 parts by weight
North Carolina kaolin	40 parts by weight

The platinum electrodes were made from platinum foil 0.05 mm. thick, cut into pieces one centimeter square or slightly larger. A 2.5 cm. length of No. 24 B. & S. gage platinum wire was welded to each of two diagonally opposite corners, which were then bent at right angles to the foil. The other two corners were also bent about 3 mm. in the same direction, so that when the electrode was embedded in the plastic porcelain body, it was firmly held in place (Fig. 2-A), and could not be bent after the porcelain had been fired. The two wires were passed through the cell walls (Fig. 2-B) and connected to the leads of the cell when in use.

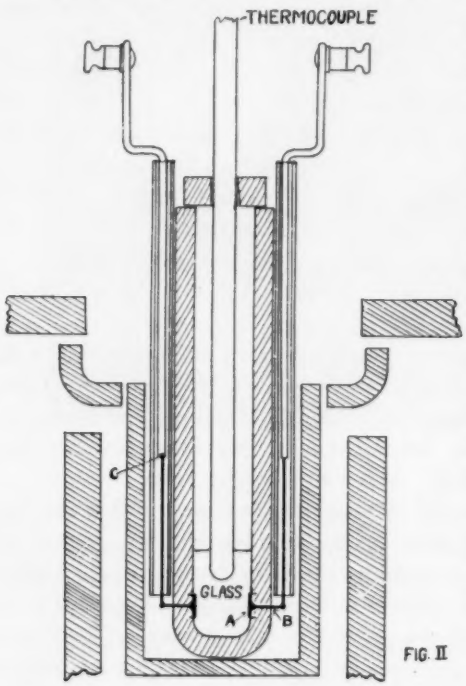


FIG. II

The cell itself was made by molding the wet porcelain mixture around an eight-inch test tube. The wall thickness was approximately 5 mm. and great care had to be taken to knead the mixture and roll it until the thickness was uniform and all laps were thoroughly joined. A hole was filed into the end of the test-tube, so that by twisting the tube around and slowly withdrawing it, it could be removed without causing the cell walls to collapse, or otherwise deform.

The electrodes were inserted while the soft body was still around the glass tube. To do this the cell was cut about 4 cm. from the closed end. The end piece was removed by a twisting motion and set on a glass plate, and the electrodes were then inserted on the inside about 1 cm. from the end. After pushing into place and pressing the porcelain closely around the corners, the end piece was again placed over the tube and the two parts worked together. Great care had to be exercised in joining these parts. If they were not well kneaded and twisted back and forth at the union, the cell would very often crack at this point on burning.

When completely molded, the cell was laid on its side on a plaster of Paris slab and the test-tube was withdrawn. After thorough drying, the cell was carefully examined to make sure no porcelain mixture was on the platinum electrodes. The cell was then burned in a gas-fired "Surface Combustion" furnace. The temperature was raised slowly to about 1400°C where it was held for about three hours. This was to make the porcelain dense and free from pores and to insure against further shrinkage when the cell was in use. The average time of burning was about nine hours.

The leads into the furnace were made as heavy as possible to have a very low resistance and temperature correction. Soft iron wire 0.312 cm. in diameter and 15 cm. long was used from the binding posts to the high temperature zone. Two 7.5 cm. lengths of No. 20 B. & S. gage platinum wire were twisted together and connected to the iron wire by drilling into its end, inserting the platinum (Fig. 2-C) and squeezing in a vice. The lower end of the platinum was connected to the wires of the cell by twisting and welding. The leads in the furnace were protected by porcelain insulating tubes, and the whole apparatus was sealed into the chamber of the electric furnace which served as an air bath tightly closed by means of a plastic fire clay and quartz sand mixture.

Preliminary Work

Soda-Lime Glass.—The glass used in this work was made from analyzed sodium and calcium carbonates and a high grade quartz sand. The raw batch was well mixed and melted in covered $4^1/_2$ inch Denver Fire Clay crucibles. The melts were made in a "Surface Combustion" furnace in about eight hours, the final temperature being about 1400°C. The molten glass was poured into iron button molds to cool. It was clear with a light bluish green tint in thick sections.

Analysis.—In order to obtain uniform samples, the glass was ground in a steel mortar, passed over a magnet, through a 100-mesh sieve, then thoroughly mixed and analyzed by standard methods.

The results of the analysis follow:

	Average
SiO_2	67.37%
CaO	16.74
Al_2O_3	.41
Fe_2O_3	.09
Na_2O	15.60
	100.21

Conductivity studies discussed later include solutions of salt in glass. The amount of sodium chloride added to the glass was determined by weighing the chlorine as silver chloride. This analysis was similar to that of the glass itself.

Specific conductivity values employed for potassium chloride solution were those obtained by Kohlrausch.[1]

Procedure

When the cell constant had been obtained, the cell was set in the furnace and sealed in place by plastic fire clay. The thermocouple was inserted and the temperature raised to 1200° in about three hours. The resistance of the empty cell was determined at 100° intervals to make a correction which generally was about +0.6% of the apparent resistance of the glass at 1000°. The resistance of cell No. 12 is given here as a typical example:

Temperature	Resistance	Temperature	Resistance
777°	11,600 ohms	1113°	1,600 ohms
855	6,500	1196	1,190
944	3,720	1228	1,110
1040	2,220	....	.....

While heating, the cell was closed with a porcelain stopper and the thermocouple. These were then removed and 25 grams of the powdered glass introduced. The temperature was raised to 1400°, until the glass was completely melted and most of the air bubbles were removed. The bubbles would stick to the platinum electrodes and were the greatest source of error. Stirring with a bright nickel or platinum rod while the glass was at high temperatures, was the only effective means of removing bubbles. The glass was freed from bubbles in as short a time as possible and the temperature lowered to about 1100° when the thermocouple was again inserted. It was necessary to determine the proper position of the thermocouple in the glass by experiment. If inserted too deeply it interfered with the conductivity measurements causing error. If not deeply enough there was a temperature error, as the glass had a temperature variation of 10–20° between its center and the upper surface. By adjusting the furnace rheostat and an auxiliary rheostat and letting the current flow

[1] Kohlrausch, Holborn and Dieselhorst, *Ann. Physik.*, **64,** 417–410 (1898); "Physikalisch-Chemische Tablellen," Landolt-Börnstein, Springer, Berlin, 1117 (1912).

constantly for 30–60 minutes, the temperature became constant around 1050°. The thermocouple was then lowered from its normal position until it was between the electrodes, and the millivoltmeter was read to learn if there was a difference of temperature. As a rule, the glass was several degrees hotter between the electrodes than around the thermocouple about 1 cm. above this point. A proportionate correction was made, and this correction decreased regularly as the furnace temperature approached room temperature.

When the temperature became constant, the oscillator was started and the resistance of the box was adjusted until the setting of the slide-wire was as near its center as possible. The variable condensers were then adjusted until the sound minimum was sharp and did not extend over more than two scale divisions. The bridge was balanced, and the millivoltmeter immediately read, after tapping the instrument to insure correct needle position. Several readings were made at a given temperature. The rheostat resistance was then increased and the current was turned off for 2–5 minutes and then turned on again for at least half an hour before the readings were taken. In this manner the temperature was lowered and held constant for conductivity measurements in approximately 50° steps. Readings of the known resistance, millivoltmeter, cold junction temperature, capacity and bridge setting were recorded. The time was also recorded to obtain the rate of cooling. Specific conductivity measurements were made from 750–1050°. The resistance of the glass changes so much over this range (about 0.7% per degree) that higher temperature measurements would call for a cell of greater resistance. The lower temperature (750°) is in the solidification range of the glass.

The cell constant is influenced slightly by temperature. It is increased when the distance between the electrodes is increased, and decreased by increasing their area. The average temperature coefficient of linear expansion of the porcelain between 0–1000° is about 0.000005. The average coefficient for platinum over the same temperature range is approximately 0.00001. On this basis, the cell constant increases by about 0.2% from room temperature to 1000°. The iron and platinum lead-in wires of the furnace increased in resistance as the temperature rose. The corrections for the cell constant and that for resistance of the leads were of opposite sign to, and almost equivalent to the correction for the conductivity of the porcelain in the cell, so practically no corrections were necessary between 750° and 1050°C.

Sodium chloride was added in 0.2, 0.4, 0.6, 0.8 and 1.0 g. lots, respectively, per 25 g. portion of glass. Baker and Adamson Chemical Company's C. P. product re-tested was employed. It was mixed with the powdered glass just before introduction into the cell. The sodium chloride vaporized partially at these high temperatures and so the amount found

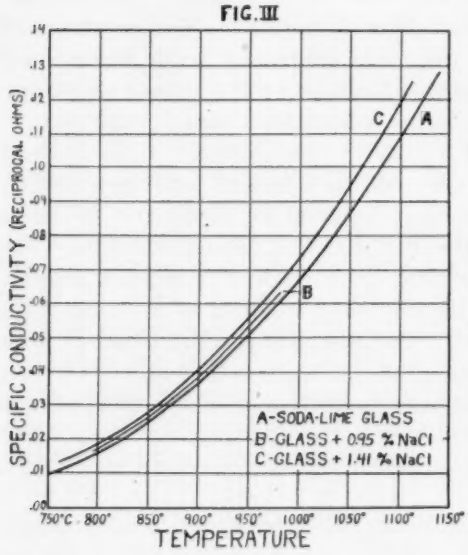
in the glass was always smaller than the amount of salt originally introduced. In the case of the two higher concentrations some salt was found on the surface of the glass after cooling, due to limited solubility. The highest portion of salt found in any specimen of glass in this investigation was 1.41%. Gelstharp[1] studied plate glasses containing sodium chloride and sodium sulfate. These were added as raw materials and in the glasses examined the sodium chloride content varied from 0.91% to 1.48%. By increasing the time or temperature of melting the sodium sulfate and chloride content was found to decrease. No change in properties due to the presence of the salts was noticed by Gelstharp, and there was no apparent difference in appearance of the glass used in this research, except a possible tendency toward devitrification. This was noticed in two specimens and occurred around the bottom of the thermocouple.

After a determination the cells were broken open and the glass examined. In every case the glass was of a light yellow-green color and nearly free from bubbles. Many cells had bubbles on the electrodes and so these determinations were discarded.

Discussion of Results

Accuracy in conductivity measurements in aqueous solutions, through introduction of improved apparatus, is of a high order. Work at the high temperatures encountered in this research is naturally less accurate for lack of control over the conditions. The results of the determinations are best shown in Fig. 3. Curve A represents the mean of four determinations of the conductivity of glass itself. Curve B shows the determination when the glass contained 0.95% NaCl and curve C when it contained 1.41% NaCl. Determinations were also made when the glass contained 1.08% and 1.30% of salt. These displayed more discrepancies than the others and are not shown in the curves. The main cause of these deviations was the variation of current in the furnace with consequent failure to keep the temperature constant.

FIG. III



[1] *Trans. Amer. Ceram. Soc.*, **14**, 655–70 (1912).

The following table gives conductivity values at various temperatures. Above 1050° the resistance of the glass in the cells became so low that sometimes capacities as high as 3 or 4 microfarads would have been necessary to produce a sharp sound minimum. This condition makes the data taken above that temperature less reliable. It is interesting to note that conductivity increases with temperature in vitreous silicate media as in aqueous solutions.

TABLE III

SPECIFIC CONDUCTIVITY

Temperature, degrees	Soda-lime glass	Per cent NaCl per 100% glass		
		0.66%	0.95%	1.41%
750	0.0099	....	....	....
800	.0163	0.0168	....	0.0184
850	.0254	.0262	0.0267	.0278
900	.0368	.0379	.0387	.0404
950	.0510	.0525	.0532	.0553
1000	.0680	....	....	.0732
1050	.0877	....	....	.0947
1100	.1097	....	....	....

The greatest deviations from the mean determination for the glass itself were about ±2.5%, but most of the values were within ±1.0%.

In Table II the specific conductivity of molten sodium chloride at 850° is 3.50. Adding 1.41% of sodium chloride to 100 of glass increases the conductivity at this temperature by about 9.41%. The conductivity at this temperature was calculated from the percentage composition as 0.0751, while the measured value was only 0.0278 and the conductivity of the pure glass was 0.0254. The calculated value of the conductivity of molten salts is also more than the observed value, the deviation being small for pairs of salts such as sodium and potassium nitrates which are highly ionized and do not react.[1] When the salts form compounds the deviation is much greater.[2] In any case the amount of sodium chloride introduced into a glass is small and experimental error makes the drawing of absolute conclusions somewhat risky.

It has been shown that in solid glass only the alkali metals are ionized at temperatures around 200–400° and about 80% of the sodium in a soda-lime glass is in the ionic state. It has also been suggested from the behavior of other complex silicates that at higher temperatures (600–1200°) silicates such as calcium and aluminum are ionized. This may partially account for the increased conductivity of glasses at very high temperatures. The viscosity is considerably lowered on melting, but the change in conductivity of the glass at temperatures in the softening range is much less than that of the viscosity itself, so other factors must be considered. The

[1] *Phys. Rev., loc. cit.*

[2] *Atti. Accad. Lincei, loc. cit.*

conductivity of a soda-lime glass at 100°C[1] is near the order of magnitude of 10^{-10} while at 750° for the glass in this work it is 9.9×10^{-3}. By approximate extrapolation of the curve in Fig. 3 the conductivity-temperature relation from room temperature to 1200° can be shown. It is possible when the glass is fluid that the silicate ions can also transport electricity as well as the mobile sodium ions.

In the past it has been customary to furnish data or discuss the conductivity of "soda-lime glass," and some investigators do not even give the latter information, simply using the term "glass" and omitting the analysis. It has been shown that the sodium content of a glass can have an important effect on its conductivity. Data to show the effect of other constituents such as CaO, Al_2O_3, etc. are meager. It is apparent that the composition of glass is so varied that classification of conductivity in general terms is undesirable.

Conclusions.—This investigation embraces a review of past work, a study of apparatus and methods for determining the conductivity of glasses and solutions of salts in vitreous media above the melting point of the solvent. Pioneer work in this field is time-consuming to a large degree before the actual determinations can be made. Hence, while conductivity data furnished are limited, the way has been paved for future work and the following conclusions and possibilities are likely.

1. A search of the literature indicates that this work is the first study of the electrical conductivity of salts dissolved in molten silicates. The conductivity of mixtures of sodium chloride and molten glass is similar in nature to other molten salt mixtures.

2. The conductivity of a soda-lime glass increases in proportion to the amount of sodium chloride added. The increase is sufficient to show ionization although the conductivity of the salt is not nearly as great as it is in molten sodium chloride at a given temperature. This might be due to several changes, such as the viscosity change in the glass, common ion effects, reaction to form compounds, etc.

3. The maximum value of sodium chloride found in plate glass by Gelstharp was 1.48%. It has been checked in this work by a value of 1.41%, though in the glasses studied by Gelstharp the salt was added to the raw batch while in this work it was added to the finished glass.

4. This investigation indicates that apparatus used for making electrical conductivity measurements of aqueous solutions is suitable for work with molten glasses when the cell described is used with suitable lead-in wires and furnace. Jaeger and Kapma[2] have described a method which has good precision, where two platinum crucibles, one inside the other, act both as container and electrodes. The resistance of such an

[1] Campbell, *Proc. Phys. Soc.* (London), **25,** 336 (1913)

[2] *Z. anorg. allgem. Chem.*, **113,** 27–58 (1920).

arrangement cannot be made very high and would require large capacities. In a glass at very high temperatures, considerable alkali might be lost by volatilization. This might not make much difference with a pure salt, but in glass where the sodium content very largely determines the conductivity, it would be important.

5. The electrical conductivity of the glass is small from 0° to 750°C, compared with the conductivity at higher temperatures. It is possible to extrapolate approximately curve A in Fig. 3 and to study the conductivity of this glass from 0–1200°C. The expression $C = a + bt + ct^2$ has been applied to the conductivity-temperature relation, where C = specific conductivity, a, b, and c are constants and t is the temperature. The constants were calculated from experimental data. The equation will fit the curve above the melting point (800–1100°) fairly well and other investigators have applied it to solid glass (100–500°), but an attempt to fit the entire extrapolated curve (0–1200°) failed. Most probably there is discontinuity at the melting point of the glass where all factors have not yet been accounted for.

6. Since sodium ions are present in opal glasses without destroying opalescence, and since the addition of negatively charged chloride or sulfate ions will remove this effect, the colloid present must be positive in its nature, if the opalescence is due to colloidal material as generally assumed. This seems to resemble the coagulation of colloidal particles in aqueous solutions by the addition of ions of opposite charge. If the colloid in molten glass is Al_2O_3, then it is probably positive as colloidal $Al_2O_3.xH_2O$ is positive in aqueous media. Since many positive sodium ions are present in opal glass the coagulation by added salt must be due to negative chloride ions.

7. Conductivity and electrolytic investigations of molten glasses of various types will most probably do much to show the nature of vitreous silicate solutions and permit of comparison with aqueous solutions. Similarity has already been implied.[1] To obtain reliable and far-reaching results, a combination study of viscosity, density, conductivity and ionic mobilities would be necessary.

8. A molten glass is most probably in equilibrium and the equilibrium in the solid state, which has been more carefully studied than in molten material, is undoubtedly different in degree, rather than in nature. This has been shown by the tempering of a glass on cooling, when the conductivity is more nearly that of the molten glass, than it is in a glass which has been slowly annealed. Research on such equilibria will probably lead to an understanding of reactions at high temperatures and of the structure of complex silicates.

[1] A. Silverman, *Jour. Ind. Eng. Chem.*, **9**, 33 (1917).

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EXACT NOTIONS OF FLUORINE ENAMELS

By Charles Musiol[1]

ABSTRACT

The theories of Vogt, Grunwald, Mayer and Havas, and others regarding the rôle of fluorine in enamels are proved by mathematical rather than chemical means to be incorrect. Fluorine is not volatilized as SiF_4, but disappears during the smelting process as F_2, although in the presence of B_2O_3 it may be volatilized as BF_3. Enamel formulas should be studied by means of the "*subtractive*" analysis method.

Introduction

Enamels used in sheet iron and cast iron enamel works are nearly all fluorine enamels. Their compositions vary according to the qualities the enamel must possess, namely, fusibility, fluidity, coefficient of expansion, opacity, and other physical and chemical qualities.

Generally fluorine enamels are solid solutions of different silicates, with which is blended the fluorine issuing from fluorine compounds, such as fluorides of aluminium, barium, calcium, sodium, natural cryolith, artificial cryolith, sodium silico-fluoride, chiolith, and others.

The effect produced by the use of simple compounds, such as Na_2O, K_2O. . . . SiO_2, etc., either basic or acid, has been defined in a more or less exact way in numerous studies of glasses and glazes. We cannot, however, say as much in regard to the effect of fluorine and fluorine compounds. Sometimes it is entirely neglected, and even omitted from formulas, as in J. B. Shaw's paper on "The Admissible Limits of the Ingredients of Sheet Iron Enamels."[2]

Fluorine Glazes and Enamels

At the Seventh International Congress of Inorganic Chemistry in London in 1909, G. Vogt, director of the National Manufactory of Sèvres, presented a very complete study of *a porcelain glaze containing fluorine*, so as to determine what part fluorine takes in fluorine glazes. This glaze had been prepared according to the molecular formula:

$$\left.\begin{matrix} 0.70\ CaO \\ 0.30\ Na_2O \end{matrix}\right\} 0.50\ Al_2O_3 \left\{ 4.0\ SiO_2 \right.$$

and was smelted at 1300°C. The batch mixture as well as the fritted glaze were analyzed, with results as shown in Table I.

The comparison of these two analyses led Mr. Vogt to the following conclusions: "These results prove that all the fluorine, introduced into the glaze by fluorspar, has disappeared during the smelting, according to the reaction:

$$SiO_2 + 2CaF_2 = SiF_4 + 2CaO$$

[1] Formerly Enamelworks director, now Technical Bureau at Brussels.

[2] *Trans. Amer. Ceram. Soc.*, **11**, 103 (1909); *Jour. Amer. Ceram. Soc.*, **3**, 492 (1920).

That this reaction really took place is proved by the resemblance of the molecular formula of the fritted glaze,

$$\left.\begin{matrix}0.715\ CaO\\0.285\ Na_2O\end{matrix}\right\}0.52\ Al_2O_3\left\{4.4\ SiO_2\right.$$

to the molecular formula, mentioned above, which served as a basis for the preparation of the glaze. The result obtained indicates that a mixture for a fluorine glaze to be smelted under the same conditions and at a temperature of 1300°C ought to contain a certain excess of SiO_2, the quantity whereof would be equivalent to the one which disappears in the form of SiF_4, so that the percentage of SiO_2 should not decrease during the fritting." As it happens, Vogt's name was so renowned in the ceramic world that nobody dreamed of doubting the accuracy of his hypothesis.

TABLE I

	Raw batch, per cent	Fritted glaze, per cent
SiO_2	68.22	70.84
Al_2O_3	13.89	14.12
CaO	3.06	10.41
Ca	4.91	....
F_2	4.65	....
$Na_2O + K_2O$	5.27	4.63
	100.00	100.00

Bock is authority for the statement:[1] "Soon after the melting of the enamel, the fluorine combines with the silica and vanishes under the form of silicon tetrafluoride."

Without submitting confirming data, Grunwald[2] affirms that during the melting of an enamel containing fluorspar, a part of the fluorine disappears in the form of silicon fluoride (SiF_4) according to the reaction

$$2CaF_2 + 3SiO_2 = 2CaSiO_3 + SiF_4.$$

He also maintains that the melting of an enamel containing cryolith is accompanied by the partial disappearance of silicon tetrafluoride.

Expressing more or less the same opinions, Eyer[3] came to the conclusion that the silicate of calcium thus formed melts with difficulty and renders enamels fragile.

In an article entitled "Phenomena of the Melting of Enamels,"[4] Mayer and Havas have published the results of their experiments with fluorine

[1] *Sprechsaal*, **40** (1908).

[2] "Abhandlungen aus der Emailtechnik," pp. 146, 153, 154 (1910); "Chemische Technologie der Emailschmaterialien," pp. 30, 109 (1911); "The Raw Materials for the Enamel Industry," pp. 22, 84 (1914).

[3] Emailwissenschaft, **1913,** page 50.

[4] *Sprechsaal*, **1** (1911).

enamels. Below are two analyses of one of these enamels—one an "ideal" analysis of the batch mixture calculated from the analysis of the materials used, and the other an actual analysis of the melted mixture:

TABLE II

	"Ideal" analysis raw batch, per cent	Actual analysis melted batch, per cent
SiO_2	50.48	51.00
B_2O_3	16.34	15.79
CaF_2	6.81	5.44
CoO	0.27	0.25
MnO	0.67	0.71
Al_2O_3	7.75	7.86
CaO	0.23	1.51
K_2O	2.38	2.60
Na_2O	15.07	14.84
	100.00	100.00

From a comparison of the mixture analysis and of the melted ground coat analysis, the experimenters drew the following conclusions:

It is evident that 20.2% of the amount of fluorine, and 3.4% of the amount of boric acid which were originally present disappear. The small increase of silica (SiO_2) is surprising, but may be explained by the fact that the fluorine escapes in the form of silicon tetrafluoride (SiF_4). The loss of boric acid is due to its great volatility at the melting temperature of 1000–1100°C. However, the fact is also recognized that a portion of the fluorine, combining with the boron, escapes in the form of boron fluoride (BF_3).

E. P. Poste and B. A. Rice[1] who, however, purposely refrained from introducing analyses of the enamels tested by them, found that the fluorine of their enamel was completely volatilized as silicon tetrafluoride (SiF_4). In the absence of their complete data, their results cannot be discussed.

Other references[2] might also be cited, but they only repeat what has already been said.

But let us consider the conclusions which these investigators have drawn:

If Grunwald and Eyer had studied the tests of the Russian Karandeef, and of the American experimenters Day, Allen, Shepherd, White, and Wright, they would have learned that the melting point of the lime silicate $CaO.SiO_2$ is in the range 1500–1550°C, and they would have deducted that at the quite lower temperature at which enamels are melted, the forming of calcium silicate is *impossible*.

[1] *Jour. Amer. Ceram. Soc.*, **1**, 221 (1918).

[2] "Ceramic Chemistry, de Stephenson," p. 46 (1912); U. S. Bur. of Standards, *Tech. Paper* **165**, pp. 28, 54.

If the fluorine had disappeared according to the reaction suggested by Vogt,

$$SiO_2 + 2CaF_2 = SiF_4 + 2CaO$$

then the volatilization of each F_4 to be found in the SiF_4 would cause the loss of one SiO_2, or, considered from a molecular weight standpoint, the loss of one part by weight of F_2 must cause a loss of 0.795 parts by weight of SiO_2. Since the analyses as given in Table I indicate a loss of 4.65% of fluorine, the silica ought to have undergone a loss of 3.695%. At the same time each Ca of the CaF_2 ought to have reappeared as CaO, which is 1.397 times heavier, or 4.91% of Ca in the raw batch should give 6.86% of CaO in the fritted glaze. Hence, according to Vogt's suppositions, the analysis of the fritted glaze ought to be as follows:

TABLE III

	Analysis raw batch, per cent		Theoretical analysis according to Vogt's suppositions, per cent	Actual analysis of Vogt's fritted glaze (see Table I), per cent
SiO_2	68.22 — 3.695	= 64.525	68.900	70.84
Al_2O_3	13.89	= 13.890	14.835	14.12
CaO	3.06 + 6.86	= 9.920	10.600	10.41
Ca	4.91 — 4.91	= 0.000	....	....
F_2	4.65 — 4.65	= 0.000	....	....
Alkalies	5.27	= 5.270	5.630	4.63
	100.00	93.605	99.965	100.00

Since Vogt's analysis contains more SiO_2 and less alkalies than would be present had the process taken place according to the reaction he suggests, it would seem that his theory may be at fault.

However, in studying the situation which has caused this misapprehension, we see that Vogt has set up for comparison two analyses, which, according to a mathematical standpoint, are really not comparable, for an analysis containing Ca + F_2 cannot be compared to an analysis where the same Ca is expressed as CaO. Vogt has also neglected the fundamental rule of Lavoisier, whose celebrated saying, *Nothing is lost,—nothing creates itself*, is well known. One cannot compare CaF_2, which has a molecular weight of 78, with the expression CaO + F_2, which has a molecular weight sum of 94.

It is evident that to completely satisfy *Lavoisier's rule*, the expression should be

$$CaF_2 = CaO + F_2 - O$$
$$78 = 56 + 38 - 16.$$

This relation teaches us that in the analysis of fluorine enamels, *it is necessary to deduct 16 ÷ 38 = 0.421 parts by weight of oxygen from each part by weight of fluorine contained in the enamel.*

"Subtractive" Method of Analysis

To thoroughly distinguish this new method of calculation from the old one, we will call it a "*subtractive*" one. In Table IV, below, the method of transforming Vogt's raw batch formula into the "*subtractive*" analysis is shown:

TABLE IV

	A	B	C	D	E	G
SiO_2	68.22	....	68.220	68.220	70.125	70.680
Al_2O_3	13.89	....	13.890	13.890	14.270	14.390
CaO	3.06	6.86	9.920	9.920	10.200	10.278
CaF_2	9.56	....	.....	....	.....	....
F_2	....	4.65	4.650	....	.....	....
Alkalies	5.27	....	5.270	5.270	5.415	4.630
	100.00	11.51	101.950	97.300	100.010	99.978
−O	....	1.957	1.957	....	.....	....
	100.00	9.553	99.993	97.300	100.010	99.978

A = analysis of Vogt's Raw Batch—see Table I.
B = CaO and F_2 represented by 9.56% CaF_2.
C = total of columns A + B.
D = same as C minus the fluorine.
E = column D divided by factor 0.973 to bring analysis total to 100.
G = same analysis corrected by fact that part of alkalies volatilized and only 4.63% is shown by analysis, and assuming that no other substances than fluorine and the alkalies suffer fire loss.

Table V, below, shows a comparison of Vogt's analysis of the fritted glaze and the "*subtractive*" analysis:

TABLE V

(Showing how closely two analyses agree)

	Vogt's analysis, per cent	Subtractive analysis, per cent
SiO_2	70.84	70.68
Al_2O_3	14.12	14.390
CaO	10.41	10.278
Alkalies	4.63	4.630
	100.00	99.978

From the above it may be concluded that the fluorine has disappeared either alone, and that the alkalies and alumina have suffered their loss independently, or that the fluorine has vanished in the form of Na_2F_2, K_2F_2, and Al_2F_6. Whatever may be the case, it is shown that there is no loss of silica (SiO_2) and that consequently there is no forming of silicon tetrafluoride (SiF_4), as Vogt supposed.

If we take Mayer & Havas's results in their original form (see Table II), rearranging the order of constituents for convenience sake, and transform them into a "*subtractive*" analysis, we shall be better able to discuss them. If we suppose, with these authors, that only the fluorine (F_2) and boric acid (B_2O_3) suffer fire loss, using the same methods of calculation employed before, we obtain the "*subtractive*" *analysis* given in column "C s" below:

TABLE VI

	A	B	C	D	E	G	C s
Na_2O	15.07	....	15.070	14.84	....	14.840	15.240
K_2O	2.38	....	2.380	2.60	....	2.600	2.407
CaO	0.23	4.8896	5.120	1.51	3.906	5.415	5.178
CoO	0.27	....	0.270	0.25	....	0.250	0.273
MnO	0.67	....	0.670	0.71	....	0.710	0.678
RO			23.510			23.815	23.776
B_2O_3	16.34	....	16.340	15.79	....	15.790	15.790
Al_2O_3	7.75	....	7.750	7.86	....	7.860	7.837
SiO_2	50.48	....	50.480	51.00	....	51.000	51.048
CaF_2	6.81	....	.....	5.44	....	.....	.....
F_2	....	3.3165	3.316	....	2.6493	2.649	2.649
	100.00	8.2061	101.396	100.00	6.5553	101.114	101.100
−O	....	1.3965	1.396	....	1.115	1.115	1.115
	100.00	6.8096	100.000	100.00	5.4403	99.999	99.985

A = Ideal analysis of raw batch (see Table II).
B = CaO and F_2 to be derived from 6.81% CaF_2.
C = "*Subtractive*" *analysis* derived from A.
D = Actual analysis of melted batch (see Table II).
E = CaO and F_2 equivalent to 5.44% CaF_2.
G = "*Subtractive*" *analysis* derived from D.
C s = Ideal "*Subtractive*" *analysis*, calculated from "C," and assuming B_2O_3 = 15.790; F_2 = 2.649; and O = 1.115.

The subtractive analysis "C s" can be calculated much more rapidly in a direct way by multiplying each constituent of the analysis "C" by a coefficient "s," derived as below:

$$S = \frac{100 - F + O}{100 - f + o} \times \frac{100 - B}{(100 - b) \times \frac{100 - F + O}{100 - f + o}}$$

where B = wt. of boric acid in analysis G
F = wt. of fluorine in analysis G
O = wt. of oxygen in analysis G

b = wt. of boric acid in analysis C
f = wt. of fluorine in analysis C
o = wt. of oxygen in analysis C

$$\text{Then } S = \frac{100 - 2.649 + 1.115}{100 - 3.316 + 1.396} \times \frac{100 - 15.79}{(100 - 16.34) \times \frac{100 - 2.649 + 1.115}{100 - 3.316 + 1.396}}$$

$$= 1.00393 \times \frac{84.21}{83.66 \times 1.00393}$$

$$= 1.00393 \times \frac{84.21}{83.596} = 1.01126$$

In Table VII (below), by multiplying the different constituents of column "C" (Table VI), (fluorine, boric acid, and oxygen excepted) by the coefficient "s" = 1.01126 and borrowing from the analysis "G" that

$B_2O_3 = 15.790$
$F_2 = 2.649$
and $O_2 = 1.115$

we obtain the Ideal "Subtractive" analysis "C s" given above.

TABLE VII

	C	Coefficient s	C s
Na_2O	15.070	1.01126	15.240
K_2O	2.380	1.01126	2.407
CaO	5.120	1.01126	5.178
CoO	0.270	1.01126	0.273
MnO	0.670	1.01126	0.678
RO	23.510	.....	23.776
B_2O_3	16.340	.....	15.790
Al_2O_3	7.750	1.01126	7.837
SiO_2	50.480	1.01126	51.048
F_2	3.316	.....	2.649
	101.396	.....	101.100
−O	1.396	.....	1.115
	100.000	.....	99.985

From a comparison of the two subtractive analyses (columns G and C s in Table VI) we see

(1) That the silica (SiO_2) and alumina (Al_2O_3) have not suffered any change exceeding the limits of analytical mistake,

(2) That the sum of the alkalies ($Na_2O + K_2O$) has changed but little, but that the phenomena of the decrease of Na_2O and the simultaneous increase of K_2O are unexplainable,

(3) That the CaO has increased somewhat through an unknown cause,

(4) That, however, the amount of the bases RO has remained without any change of note.

Fluorine undergoes only a partial volatilization and there is a small loss of boric acid (B_2O_3).

As there is no decrease of silica (SiO_2) *there cannot be any formation of silicon tetrafluoride* (SiF_4) *whatever.*

However, we must call attention to the discrepancies in the analysis. Why the great increase in CaO, the decrease of Na_2O and of CoO, and the increase of K_2O and MnO? Are these caused by the inaccuracy of the analysis or by an error of writing?

Space allowed in this *Journal* will not permit a detailed study of the other ground coats,[1] but suffice it to say that in all these studies the constituents Na_2O, K_2O, and CaO behave quite erratically, sometimes increasing and sometimes decreasing, but that the silica (SiO_2) either does not change, or at worst, loses but a fraction of a per cent, and not enough to cause the loss of an appreciable amount of fluorine as silicon tetrafluoride (SiF_4).

Analyses are submitted by Mayer and Havas in which the enamel under consideration was smelted at higher temperatures than formerly, and in these cases the loss of fluorine increases. However, it is probably because of the higher smelting temperature that the volatilization of fluorine increased.

Fluorine Glasses

Attention should also be called to Mayer and Havas' tests of *fluorine glasses.* The starting point of these glasses was a boric acid glass which they called "normal glass II," whose analysis is as follows:

	Per cent
Na_2O	18.14
B_2O_3	19.09
Al_2O_3	11.17
SiO_2	51.60
	100.00

The batch mixtures of these fluorine glasses were obtained by the addition of 2.5%, 5.0%, and 7.5% of different fluorides with respectively 97.5%, 95.0%, and 92.5% of "normal glass II." After melting, each fluorine glass was analyzed, and the data submitted by them and reproduced in *Chimie et Industrie* (*loc. cit.*) shows that the "*normal glass II,*" *with different fluorides added, behaves in a quite different manner than the fluorine enamels.* In these glasses *the silica* (SiO_2) *does not undergo any change,* the alkalies and boric acid do not volatilize, and on the contrary,

[1] See *Chimie et Industrie,* **2,** 872–87 (1923), for complete data.

TABLE VIII

No.	Vogt's glaze 1	Ground-coats 2	3	4	White enamels 5	7	Mixture of normal glass II and CaF_2 2.5% 8	CaF_2 5% 9	Na_2P_2 5% 10	Na_2P_2 10% 11	Al_2F_6 5% 12	Al_2F_6 10% 13	Cryolith 5% 14	Cryolith 10% 15
Na_2O	87.85	97.38	102.75	101.31	101.75	96.95	99.87	100.05	99.98	99.94	100.07	100.08	100.03	99.86
K_2O		108.02	103.01	101.14	103.10	89.40	....	....	....	....	....	....	....	....
CaO	101.28	104.58	99.56	100.07	99.72	147.95	98.17	93.65	....	....	....	....	....	....
CoO	....	91.61	104.48	102.65	....	....	....	....	....	....	....	....	....	....
MnO	....	104.72	103.45	101.35	....	....	....	....	....	....	....	....	....	....
B_2O_3	....	96.63	97.50	97.00	93.10	96.30	100.20	100.50	100.19	100.4	100.7	101.56	100.19	100.58
Al_2O_3	98.75	100.25	102.87	101.18	102.01	112.25	99.95	100.01	99.95	100.06	99.77	99.50	99.96	100.00
SiO_2	100.72	99.93	99.13	99.39	98.99	98.61	100.05	100.45	100.07	100.03	100.07	100.11	100.07	100.04
F_2	....	79.87	75.95	78.00	88.13	83.85	67.20	64.50	84.25	85.30	62.80	63.80	85.60	84.00
$-O$	....	79.87	75.95	78.00	88.13	83.85	67.20	64.50	84.25	85.30	62.80	63.80	85.60	84.00

the latter *undergoes an increase* that we cannot explain. It may be occasioned by an erroneous calculation, or an inaccurate analysis, but whatever the cause, these tests *prove that there is no formation of silicon tetrafluoride*, and that the fluorine (F_2) vanishes in molecular form.

In order to see how the different compounds are affected in the smelting process, a study should be made of Table VIII. The values in this table represent the per cent of each constituent remaining in the enamel, *considering the amount which should theoretically be there as 100%*.

The small number of tests considered, and their inaccuracy do not allow setting up any definite rule which will express the change of enamel constituents as a function of the enamel composition. Our general conclusions, which follow, do not, therefore, claim to lay down a law.

Conclusions

The data which have been submitted demonstrate that *the volatilization of fluorine depends chiefly on thermal conditions, i. e.*, the smelting temperature, and its duration (compare No. 5 and No. 7)—then, *second, on the enamel composition* (compare No. 3 and No. 9) and *last, on the fluoride added* (compare No. 9 and No. 14).

The quantity of fluorine remaining in the ground coats varies from 78% to 80% of the original quantity. In white enamels it varies from 84% to 88%. It is true that the volatilization of fluorine increases in more siliceous enamels, but not owing to the increase of silica, which was supposed to be transformed into silicon tetrafluoride, but because the silica increase, by augmenting viscosity and decreasing fusibility, requires a higher and more prolonged smelting temperature.

The rôle which boric acid (B_2O_3) plays is strange, for it shows an *increase* in *glasses* containing fluorine and a *decrease* in *enamels*. In ground coats there remains 96.6% to 97.5%, while 93.0% to 96.3% remains in white enamels. We cannot give any rule for these changes, but it is evident that the volatilization of boric acid *diminishes* when fluorine *increases*.

There can be no scientific explanation for the 99.6% to 148% variation of calcium oxide (CaO). The variations of the alkalies in the enamels is quite suspicious, especially in view of the fact that in the glasses containing fluorine the alkalies showed great stability.

Silica changes least of all in these analyses. It does not change in the fluorine glasses, nor in Vogt's glaze, which had the highest percentage of silica of any of the compositions. In all cases there remains from 98.61% to 99.93% of the silica theoretically there. *The maximum loss of silica (1.39%) which we have found, would, at the most, allow of the formation of only 2.4% of silicon tetrafluoride (SiF_4) for 100% of melted enamel, which corresponds to but 10.8% of the total loss of fluorine.*

This ought, at least, *to put in grave doubt, the theory that fluorine vanishes as silicon tetrafluoride.*

Perhaps before concluding, we should here take cognizance of the fact that fluorine may combine with boron and vanish in the form of boron fluoride (BF_3), as suggested by Mayer and Havas and referred to earlier in this paper. Boron combines with fluorine according to the equation:

$$B + F_3 = BF_3$$
$$11 + 57 = 68$$

from which we may see that $^{11}/_{57}$ parts by weight of boron are required to combine with 1 part by weight of fluorine.

If we calculate from the loss of fluorine the amount of boron which would be lost by such a reaction taking place on some of the enamels from Table VIII, we obtain values as given below:

TABLE IX

No. of enamel	2	3	4	5	7
Amt. boron by analysis	96.63	97.50	97.00	93.10	96.30
Amt. boron by calculation	96.12	95.36	95.76	97.71	96.88

These values are so closely connected that one would be tempted to conclude, that, at least in the ground coats examined, all of which contain B_2O_3, that *the volatilization of fluorine takes place almost entirely under the form of boron fluoride.* The proof of such a conclusion, would, of course, rest almost entirely upon the gas analysis.

DISCUSSION

BY J. E. HANSEN[1]

It is unfortunate that Mr. Musiol does not substantiate his rather novel conclusions as stated in his paper on "Exact Notions of Fluorine Enamels" with *chemical data*, showing either the *absence* of silicon tetrafluoride in the by-product gases, or the *presence* of definite fluorine compounds of different nature, rather than basing his conclusions on a "mathematical proof," in which there is the possibility of a fallacy, as will be shown below.

The following figures give the analysis of a ground coat enamel batch before smelting (Analysis "A"). If it is *assumed that all the fluorine* (F_2) *in the batch is driven out as silicon tetrafluoride* (SiF_4), and that there is

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no fire loss of other constituents, we derive the analysis "B," which, when corrected for the loss of SiF_4 and multiplied by the proper factor to give 100%, gives us analysis "C." This analysis would show a difference in SiO_2 from the original batch of 0.4%, or less than 0.8% of the silica present, with other constituents higher, *and yet all the F_2 "disappeared" as SiF_4.* However, if we assume a loss from the batch of 0.35% B_2O_3 and 0.35% Na_2O, as could easily take place according to Poste and Rice,[1] we find that our analysis, when corrected to total 100% (analysis "Cx"), gives us a value for SiO_2 which is identical with that in the raw batch analysis, and which, on the surface, would indicate "no loss in SiO_2."

Certainly in this case no one would say that "since no silica (SiO_2) was lost there was no formation of silicon tetrafluoride (SiF_4)," especially since the formation of SiF_4 was the assumption on which the calculations were made. Neither will it be necessary to suggest clerical errors or an inaccurate analysis to account for increases in other constituents of the analysis, for when one constituent disappears from the analysis, all others must increase in a constant ratio if the analysis is to total 100%.

The writer does not contend that the fluorine left the enamel batch in the form of silicon tetrafluoride, for he has done no research on the subject to prove or disprove it, but the offering of the above figures points out that a mathematical explanation of an analysis of the smelted enamel cannot prove in what form the constituents, which were driven off, left the batch. Only an analysis of the gases which left the enamel could show that.

Together with Mayer and Havas, and with Mr. Musiol, the writer admits the great probability that the fluorine may have been driven off in combination with boron, as boron fluoride. The reaction in such a case might be of the type

$$3CaF_2 + B_2O_3 = 3CaO + 2BF_3.$$

However, issue can be taken with Mr. Musiol on his statement in connection with the discussion of Mayer and Havas' "fluorine glasses" that "these tests prove that there is no formation of silicon tetrafluoride, *and that the fluorine (F_2) vanished in molecular form*" (the italics are the writer's). Any reaction whereby fluorine can be driven off as F_2 from fluorspar, cryolite, sodium fluoride, or aluminum fluoride by heating, is, as far as the writer can learn, new to ceramics and chemistry, and the statement ought to be substantiated by a more full proof.

Fluorine is known to be one of the most active, if not *the most active* element known to chemists. Crystallized silicon and amorphous boron, when thrown into fluorine gas, take fire and burn, with the formation of fluorides. The alkali metals and the alkaline earth metals also ignite in

[1] *Jour. Amer. Ceram. Soc.*, **1**, 221–234 (1918).

Analysis	"A" Per cent
SiO_2	50.90
B_2O_3	13.85
Al_2O_3	5.70
Na_2O	17.40
K_2O	1.69
CaO	0.16
CaF_2	7.56
NiO	0.57
MnO	1.03
CoO	1.14
	100.00

Assume all F_2 volatilized as SiF_4

$$2\,CaF_2 + SiO_2 = 2CaO + SiF_4$$
$$156 \quad 60.3 \quad 112 \quad 104.3$$

$\frac{60.3}{156} \times 7.56(\%\ CaF_2) = 2.93$ loss in SiO_2

$\frac{112}{156} \times 7.56(\%\ CaF_2) = 5.43$ gain in CaO

$\frac{104.3}{156} \times 7.56(\%\ CaF_2) = 5.06\%\ SiF_4$

	"B" Per cent
SiO_2	47.97
B_2O_3	13.85
Al_2O_3	5.70
Na_2O	17.40
K_2O	1.69
CaO	5.59
NiO	0.57
MnO	1.03
CoO	1.14
	94.94
SiF_4	5.06
	100.00

Divide by .9494

SiO_2
B_2O_3
Al_2O_3
Na_2O
K_2O
CaO
NiO
MnO
CoO

Arbitrarily assume a loss of 0.35% B_2O_3 and 0.35% Na_2O, as per Poste and Rice, *Jour. Amer. Ceram. Soc.*, **1**, 221–234, (1918).[1]

	"Bx" Per cent
SiO_2	47.97
B_2O_3	13.50
Al_2O_3	5.70
Na_2O	17.05
K_2O	1.69
CaO	5.59
NiO	0.57
MnO	1.03
CoO	1.14
	94.24
SiF_4	5.06
Loss $Na_2O + B_2O_3$	70
	100.00

Divide by .9424 to make total = 100%

	"Cx" Per cent	
SiO_2	50.90	same SiO_2 cont as in Analysis "A"
B_2O_3	14.32	
Al_2O_3	6.05	
Na_2O	18.10	
K_2O	1.79	
CaO	5.93	
NiO	0.61	
MnO	1.09	
CoO	1.21	
	100.00	

[1] Of course there are other smelting losses besides B_2O_3 and Na_2O, but it is not necessary to include them to p
in question—that all F_2 could go off as SiF_4, and still SiO_2 be equal to or even higher in the smelted enamel than in the r

	"B" Per cent		"C" Per cent
SiO_2	47.97		SiO_2 50.50
B_2O_3	13.85		B_2O_3 14.60
Al_2O_3	5.70		Al_2O_3 6.01
Na_2O	17.40	Divide by	Na_2O 18.34
K_2O	1.69 →		K_2O 1.78
CaO	5.59	.9494	CaO 5.89
NiO	0.57		NiO 0.60
MnO	1.03		MnO 1.08
CoO	1.14		CoO 1.20
	94.94		100.00
SiF_4	5.06		
	100.00		

% B_2O_3 and 0.35% Na_2O, as
. *Ceram. Soc.*, **1**, 221–234,

	"Cx" Per cent	
SiO_2	50.90	same SiO_2 content as in Analysis "A"
B_2O_3	14.32	
Al_2O_3	6.05	
Na_2O	18.10	
→ K_2O	1.79	
0% CaO	5.93	
NiO	0.61	
MnO	1.09	
CoO	1.21	
	100.00	

O, but it is not necessary to include them to prove the point
or even higher in the smelted enamel than in the raw batch.

the gas. If fluorine gas escapes *as such*, from a bath of molten enamel, it is a phenomena hitherto unknown by chemists.

Mr. Musiol has supplied us with that celebrated quotation of Lavoisier's, "Nothing is lost, nothing creates itself," but he does not explain where he gets the oxygen which replaces the fluorine of the fluorspar, or unites with the Ca of the CaF_2 to form CaO. Truly, there is always a certain amount of sodium or potassium nitrate (an oxidizing agent) in an enamel batch mixture, but, as a rule, not enough to supply the oxygen needed to form CaO from the Ca present in CaF_2. The writer is at a loss to explain where such oxygen comes from, unless it be from one or more of the following type "double decompositions:"

$$2RF_2 + SiO_2 \longrightarrow 2RO + SiF_4$$
$$3RF_2 + B_2O_3 \longrightarrow 3RO + BF_3$$

or

$$2R_2F_6 + 3SiO_2 \longrightarrow 2R_2O_3 + 3SiF_4$$
$$R_2F_6 + B_2O_3 \longrightarrow R_2O_3 + 2BF_3$$

EUROPEAN PRACTICE IN THE MANUFACTURE OF ENAMELED CAST IRON WARE

By Julius Grunwald

The following review of European practice in the enameling of cast iron ware, particularly as employed in Austria and Germany, will be of interest to the enamelers in the United States. The methods used in these European countries differ considerably from the general practice in American plants.

Manufacture of Cast Iron Utensils

In the manufacture of thin wall castings to be enameled, there are two principal conditions to be considered in calculating the cupola charge; (1) the softness of the iron required, and (2) the necessary fluidity of the iron. Both conditions must be carefully considered in mixing the iron. The softness of the iron is necessary in order to avoid cracking of the casting, the walls being only $^1/_8$ of an inch thick. The greatest fluidity of the iron is necessary to effect the pouring of the thin ware and hot iron is absolutely essential.

It is not difficult to obtain proper mixtures of iron for this ware. The castings do not require any special or expensive grade of pig iron. To obtain the required degree of softness in the iron it is best to use good haematite iron with about 2.5% silicon, 1.7–1% manganese,

Table I

Type of pig iron	Silicon, per cent	Manganese, per cent	Phosphorus, per cent	Sulphur, per cent	Copper, per cent
Haematite	2.0–3.0	below 1.3	below 0.1	below 0.04	.....
Foundry pig iron No. I	below 2.5	below 1.0	below 0.6	below 0.04	.....
Foundry pig iron No. III					
a. Rhineland-Westphalia	1.0–2.5	below 1.0	below 0.9	below 0.06	.....
b. Siegerlander	1.8–2.0	below 1.0	below 0.9	below 0.06	.....
Puddled iron of best quality					
a. Rhineland-Westphalia	.....	2–3.0	0.3–0.5	below 0.08	below 0.35
b. Siegerlander	.....	3.0–5.0	0.3–0.5	below 0.08	below 0.35
Steel iron					
a. Rhineland-Westphalia	.....	4.0–6.0	below 0.1	below 0.04	below 0.30
b. Siegerlander	.....	4.0–6.0	below 0.1	below 0.4	below 0.40
Thomas-iron					
a. Mn	.....	below 2.0	1.8	0.12	.....
b. M.M.	.....	about 1.5	1.8	0.12	.....
c. C.M.	.....	below 1.0	1.8	0.12	.....

0.06–0.09% phosphorus and 0.03–0.05% sulphur. It is the rather high percentage of silicon of the haematite iron that gives the required softness to the iron and insures a gray fracture even in thin-walled castings. In order to obtain the highly fluid condition that is necessary, pig iron with a high percentage of phosphorus is used. For this purpose special types of Luxembourg pig iron have been introduced in Germany, these having a large percentage of phosphorus. The composition of the various pig irons employed are given in Tables I and II.

TABLE II

Type of pig iron	Total carbon	Si	Mn	P	S	Cu
Foundry pig iron No. I Dill-Lahn	3.89	0.62	0.64	0.67	0.013	0.004
Upper Silesia	3.42	2.92	0.76	0.48	0.042	0.030
Foundry pig iron No. III Lorraine-Luxembourg	3.58	1.17	0.41	1.71	0.014	0.003
Foundry pig iron Kupferhutte (charcoal-pig iron as a substitute)	4.02	0.84	0.29	0.06	0.052	0.082
Charcoal pig iron (gray)	3.41	1.41	0.39	0.73	0.092	0.011
Charcoal pig iron Siegerlander	3.0–4.0	1.0–3.0	0.3–0.5	0.20	trace	trace
Bessemer pig iron	3.76	2.52	3.90	0.07	0.03	trace
Spiegel iron Siegerlander	4.0–5.0	0.3–0.5	6.0–30.0	0.06	0.1	0.2–0.3
Ferro-manganese	5.5–7.0	0.1–1.5	below 85	0.18	trace	0.02–0.3
Ferro-silicon	1.0–1.5	8.5–15	1.0–4.0	0.08	0.02	0.02–0.3

Before giving the proper mixtures it is necessary to know the analysis of the finished castings. A typical composition is shown in Table III.

TABLE III

COMPOSITION OF TYPICAL GERMAN CASTINGS

	Per cent
Silicon	2.4
Manganese	0.5–0.7
Phosphorus	1–1.1
Sulphur	0.05–0.07

The author suggests the following range of compositions as most satisfactory for castings to be enameled.

	Per cent
Carbon	3.5
Silicon	2–2.5
Phosphorus	1–1.4
Manganese	0.5–0.7
Sulphur	0.05 to 0.08 at most

Since an excess of sulphur makes the iron refractory, a coke with the smallest percentage of sulphur is necessary for proper smelting of the iron. In order to make the sulphur of the coke inactive or to prevent the iron from being enriched by the sulphur of the coke, care must be taken to distribute the limestone uniformly on the coke so that the sulphur may be combined and removed with the slag. Excess sulphur also decreases the fluidity of the iron and causes blistering of the enamels. The addition of ferro-silicon of high percentage cleans the metal bath and softens the iron. Typical iron mixes are shown in Tables IV, V, and VI.

TABLE IV

MIX FOR BATH TUBS, 1/4–3/8" THICK

	Per cent
Haematite	30
Luxembourg III	35
Siegerlander white	5
Light scrap castings	30

TABLE V

MIX FOR ENAMELED HOUSEHOLD UTENSILS

	Per cent
Luxembourg III	15
German III	20
English	20
Scrap castings	20
Soft cast iron scrap	25

TABLE VI

TYPICAL MIXES OF IRON IN GERMANY

	a Per cent	*b* Per cent
Haematite iron	30	20
Luxembourg iron III	35	35
Cast iron scrap	..	20
Foundry scrap	35	25

In order to obtain good castings for enameling purposes pulverized graphite must not be used in the molds. The use of pulverized talc or a mixture of ground charcoal and clay is recommended.

Preparation of Castings for Enameling

Pickling is an absolute necessity. After having been heated to a dull red in the muffle furnace at about 850°C (1560°F) without nesting, the goods are pickled in sulphuric acid of 10° Baumé for about 40 minutes. By introducing steam the pickling bath is heated to 60–70°C (140–160°F). The goods are then rinsed in water to remove the excess of acid, after which they are scrubbed by means of wire brushes or combs, sand being used only when the latter are not satisfactory. The castings are rinsed again and then placed for a moment in a boiling soda solution containing about 3–4% of soda. Finally they are quickly and thoroughly dried on drying-boards as is done with sheet ware. Should there still be some dark spots remaining they are to be removed by means of a file. Large stains must be removed by further pickling and scrubbing. The pickled goods must show a uniform, gray, silvery, metallic surface. The castings are now ready for the application of the ground coat.

The following batch is typical of a suitable ground coat frit for cast iron utensils: flint 14, borax 4, fluorspar, 4.

These materials are carefully mixed, sifted and then placed in cast iron pans, 20″ x 12″ x 4″. The inside of the pan is first coated with a wet paste of clay 1/4 inch thick. The pan thus prepared is filled with the ground mass just below the rim, and it is then placed in the muffle furnace for 2 to 3 hours (the exact time has to be found by experience according to local conditions.) Generally the mass is kept fritting until ebullition caused by the escaping of the water of crystallization of the borax has ceased and a smooth frit of a highly porous character is obtained. Three test batches fritted 1, 2, and 3 hours should be ground separately. Fritting in the muffle furnace is done best at a time when it is not being used otherwise. The pan is withdrawn and entirely cooled. Then the fritted mass is broken with the aid of a small hammer and removed. Special care should be taken to reject pieces of clay or iron scale which may adhere to the frit. The frit thus obtained is ground in the wet mill together with the following ingredients: Frit 12 parts, heated quartz 4 parts, clay for enameling purposes 1 1/2 parts, and water 6–7 parts. This batch is ground to pass a 40-mesh sieve.

Before applying the ground coat upon the goods, these are wiped with a slightly moistened rag, especially the bottom (in order to prevent the layer of enamel deposited there becoming too thick). The ground mass is applied to smaller articles by slushing in a manner similar to that used for sheet metal. Too thick a layer of ground coat must be avoided as well as too thin a layer. Experience will lead to the proper thickness of enamel to be applied. Drying must be done immediately in the drying stove to prevent rusting of iron.

The ground coat ware is burned at the same temperature as for sheet metal, this temperature being 900–950°C (1650–1740°F). Burning the ground mass requires special attention as production of good ware is dependent upon it. Burning too sharply will cause what is called "over burning;" under burning may cause cracking of the ground coat after cooling. A criterion of proper burning is that the fired ground coat cannot be scratched with the finger nail.

The cover coat is applied in the same way and as a rule is of the same composition as those used on sheet steel. Cast iron utensils require only one cover coat.

If there are larger pieces of rejected ware, it is advisable in order to reclaim the casting to remove completely the ground coat by sand blasting. If only a part is damaged these areas can be coated with a ground mass and enameled after local sand blasting. In this way it is possible to secure second-class goods at least.

VIENNA, AUSTRIA

THE RELATION OF TEXTURE AND COMPOSITION OF CLAYS[1]

By Frank F. Grout[2]

ABSTRACT

Twelve Minnesota clays of diverse origin and character, which had been analyzed, were separated mechanically into five fractions, from coarse sand to fine clay, and each fraction was analyzed.

Silica is at a maximum in the fine sand portion of most clays. Alumina, iron oxides and potash are at a minimum in this portion, but while they rise a little in the coarse sand, they reach their highest proportion in the fine clay portion. Other oxides show less regularity.

An estimate of the minerals is made on the basis of all available information, though it may never be possible to tell how much colloidal material is present, making the calculation inaccurate. It seems clear that kaolinite and limonite are larger in clays than in silts, while quartz and carbonates are smaller. Others are less regular.

A detailed comparison of "fluxing constituents" and the temperatures of viscous fusion, led to the suggestion that the behavior of a clay in firing is determined not so much by the total fluxes as by the proportion of fluxes in the fine clay fraction. If this proves to be true, as it seems to be in the Minnesota clays, it should be possible to foretell more accurately than heretofore, the thermochemical and physical changes, on the basis of preliminary laboratory work. Not only the firing of the clay itself, but its effect on admixtures of other clays and its modification by washing can be fairly well estimated from a combined mechanical and chemical test.

Introduction

The determinations reported in this paper were made with a view to finding the distribution of the common elements in the portions obtained by mechanical separation of the several sizes of grains in a series of clays. Such results may (1) aid the petrographer in estimating the minerals of clays of several types, (2) aid the clay users in determining whether a washing process or a mixture of materials will improve a clay, and (3) possibly furnish a basis for more accurate correlation of the behavior of a clay in firing with its analytical composition.

It has long been understood that chemical analysis alone is not a satis-

[1] Received Nov. 29, 1923.

[2] Much of the work here reported was done by the writer in connection with the preparation of a report by the Minnesota Geological Survey on the clays and shales of Minnesota. (Minn. Geol. Surv., *Bull.* **11** (1914). See also U. S. Geol. Surv., *Bull.* **678** (1919). Credit is there given for a few analyses made by assistants.) Hearty thanks are due to the Survey for the privilege of using the samples collected through the state. Some of the analyses of "whole clay" were published in that report. Further tests have been made partly by the writer and partly by student chemists, S. F. Darling, Douglas Manuel, and C. W. Sanders, working under a grant from research funds of the Minnesota Graduate School. Grateful acknowledgments are here given for that assistance. Where doubt arose as to any student determination, the writer has run check analyses if material was available, and takes all responsibility for the approximate correctness of the data. The lack of agreement between the whole clay and sum of fractions is not much greater than is to be expected in chemical work by different student chemists.

factory index of the behavior of a clay. Purdy and Moore say:[1] "While thermochemical and physical changes follow definite laws they cannot be foretold by any analysis of primary causes...now known." It is with a hope of approaching such a forecast that the present work has combined a study of *texture and chemistry*. More data are needed along the same lines before we can be confident of the fundamental value of the scheme, but it is suggested for further work. The combined analyses are, of course, too expensive to consider as a method of daily check on factory operations. Nevertheless such methods may not be in any way too difficult (if as reliable as they seem) to use in predicting the value of a large deposit under conditions of washing or admixture of other clays.

Many men have called attention to the importance of fineness of grain in ceramics, from the time of Seger to the present day. The publications of the AMERICAN CERAMIC SOCIETY contain excellent articles on the topic.[2] Some of the behavior of a clay also depends on the form of combination of the constituents. It seems, however, that if a clay has a certain proportion of fine and coarse grains, and each portion has a definite composition, another clay with the same mechanical analysis and the same chemical composition in each fraction, ought to behave similarly in the fire. The mineral composition may still affect the behavior to some extent, but in the finer sizes such as make up many clays, reaction would take place very rapidly, and once reaction occurs, the composition would determine its behavior.

Only a little work of this sort has been done on clays. A preliminary study of the relation of fineness to composition was made by the writer in 1905 on a composite sample of West Virginia clays.[3] While the results in such a composite are not of direct ceramic value, several points of general application were noted. The United States Bureau of Soils has made a number of similar determinations on soils,[4] but the proportion of silt and clay (not always reported) is smaller in loams than in most clays; and the finer sizes were not separated in their work, whereas in clays the most significant points depend on the separation of fine and coarse clay and silt. Sven Odén analyzed a series of fine clay fractions of a Swedish glacial deposit.[5] Widman tested similarly the fractions of a weathered granite.[6]

[1] R. C. Purdy and J. K. Moore, *Trans. Amer. Ceram. Soc.*, **9**, 314 (1907).

[2] Purdy and Moore, *op. cit.* See also H. Ries, *Trans. Amer. Inst. Min. Eng.* (1903).

[3] West Va. Geol. Surv., **3**, 60–62 (1906).

[4] L. A. Steinkoenig, "Distribution of Certain Constituents in the Separates of Loam Soils," *Jour. Ind. Eng. Chem.*, **6**, 576 (1914).

[5] A series of papers reported in *Bulletins of the Geol. Inst. of Upsala*, **15** and **16** (1916–1919).

[6] Widman, R., *Bull. Geol. Inst. Upsala*, **8**, 184 (1908).

Description of Samples

The samples for this test were selected from several hundred clays collected by the writer and assistants in several parts of Minnesota. The nature of the deposits is indicated in the tables. They range geologically from pre-Cambrian residual clay through Ordovician and Cretaceous shales to Pleistocene and Recent clays. Chemically some are rich in iron, some in lime, some in silica, some in alkalies. No effort was made to choose the highest grade clays, though nearly all are serving some ceramic purpose. The use of the clay is also given in the tables. Details of the behavior in manufacture and firing are given at greater length in the Survey bulletins.

Preparation of Separates

Twenty-gram samples were shaken in bottles with water to which a few drops of ammonia had been added. Lumpy shales were in certain cases gently rubbed with a rubber tipped pestle. The disintegrated sludge was then washed through sieves and centrifuged approximately as described in *Bulletin* **84** of the United States Bureau of Soils. The diameters were checked by microscopic measurement and few grains in any separate varied from the following.

A.	Fine clay[1]	0.0 to .001 mm.	D.	Fine sand	.05 to .5 mm.
B.	Coarse clay[1]	.001 to .005 mm.	E.	Coarse sand	over .5 mm.
C.	Silt	.005 to .05 mm.			

Most of the separations were made by the writer; a few were made by students under his direction. The results in a check test are essentially similar to those obtained by the United States Bureau of Standards.

Methods of Analysis

The determinations were made by methods based on those by Hillebrand,[2] but modified slightly where material was scanty. Too much organic matter is present in most clays to allow a reliable estimate of ferrous oxides. In most cases also, on account of the organic matter, loss on ignition is reported rather than combined water, though the error in estimate of water is believed to be small; organic matter may be of small weight and still have a reducing action.

Silica, iron oxide, alumina, titanium oxide, lime, and magnesia were determined in a half-gram sample. Moisture, loss on ignition, and in

[1] It is perhaps an error to class as "clay" all the grains less than .005 mm. in diameter, but the term is retained here as the common usage. The error of several methods of estimating "clay substance" in clays was shown in the clay report of the West Virginia Geol. Surv., **3**, 26.

[2] U. S. Geol. Surv., *Bull.* **700**.

TABLE I

Clay No. 1. Gray drift, Hutchinson, Minn. Commercially washed to remove pebbles and used for brick and drain tile.

		Fractions				
	Whole clay	Coarse sand 17.1%	Fine sand 24.7%	Silt 38.6%	Coarse clay 12.0%	Fine clay 7.6%
Silica	58.85	53.26	75.72	53.20	46.44	47.0
Alumina	7.25	6.48	7.16	8.76	14.82	16.5
Iron oxides	4.97	2.54	1.72	3.27	7.52	10.5
Magnesia	3.45	5.00	1.76	5.00	3.16	3.0
Lime	9.42	14.40	6.56	12.04	8.84	4.5
Soda	1.37	1.34	.92	2.14	1.06	.9
Potash	1.76	1.66	1.44	2.08	2.38	2.5
Ignition	2.10	15.22	1.24	3.29	5.01	9.0
Carbonic acid[1]	9.10		4.00	8.34	6.85	
Moisture[2]	2.10	.32	.06	1.04	3.60	4.6
Titania	.36	.18	.14	.61	.92	.8
	100.73	100.40	100.72	99.77	100.60	99.3
Fluxes	*21.0*	*25.0*	*12.4*	*24.5*	*23.0*	*21.5*

[1] CO_2 estimated on small amounts of material. Where estimated, it is subtracted from total loss on ignition. Analysis of whole clay in U. S. Geol. Surv., *Bull.* **678** has a typographical error.

[2] Sands had visible quartz, orthoclase, dolomite, trap rock, etc. Clays slightly coherent as if colloidal.

TABLE II

Clay No. 2. Cretaceous clay, clay bank near Red Wing, Minn. Commercially washed to purify it, and used for stoneware.

		Fractions				
	Whole clay	Coarse sand 1.0%	Fine sand 6.5%	Silt 49.8%	Coarse clay 16.0%	Fine clay 26.7%
Silica	69.92	37.0	91.28	79.16	53.32	45.85
Alumina	17.39	1.7	.77	11.59	29.24	32.96
Iron oxides	1.68	47.4	5.17	1.68	2.46	2.62
Magnesia	1.11	2.0	.73	.97	1.16	1.73
Lime	.60	1.7	.78	.46	1.32	1.04
Soda	.07	N. d.	.12	.04	1.04	1.28
Potash	2.25	N. d.	.90	1.46	2.48	1.79
Ignition	5.45	9.6	.84	3.02	7.32	9.02
Moisture	1.10	.9	.00	.08	1.08	3.52
Titania	.63	N. d.	trace	1.49	1.46	.74
	100.20		100.59	99.95	100.88	100.55
Fluxes	*5.7*	*51.1*	*7.7*	*4.6*	*8.5*	*8.5*

Sands had visible limonite (concretionary), quartz, muscovite, and a little black mineral.

Clays formed a crust or scale as if largely colloidal.

some cases alkalies, were determined in a second half-gram sample. Where CO_2 was abundant it was determined on a gram sample and the amount

TABLE III

Clay No. 3. Decorah (Ordovician) shale, St. Paul, Minn. Used for fancy building blocks and brick and tile.

		Fractions				
	Whole clay	Coarse sand .7%	Fine sand 1.5%	Silt 46.8%	Coarse clay 13.2%	Fine clay 37.8%
Silica	56.35	60.0	61.8	57.20	52.20	50.30
Alumina	18.63	7.0	10.3	19.78	23.88	22.02
Iron oxides	6.19	1.8	3.0	5.20	5.80	6.54
Magnesia	2.97	.4	2.3	1.88	2.84	3.32
Lime	.96	10.9	5.4	1.45	.96	1.05
Soda	.25	.2	.8	1.34	.70	.68
Potash	7.37	4.8	4.9	6.90	6.62	6.70
Ignition	4.81	10.8	5.3[1]	2.12[1]	4.90	5.94
Carbon dioxide	N. d.	Large	1.9	1.78	None	None
Moisture	2.41	1.5	2.9	1.40	1.80	2.64
Titania	.65	.2	.5	.72	.92	.78
	100.59	97.6	99.1	99.77	100.62	99.97
Fluxes	*17.7*	*18.1*	*16.4*	*16.8*	*16.9*	*18.3*

Sands show calcareous fossils, quartz and limonite.

[1] "Ignition" has been reduced by amount of carbon dioxide determined.

TABLE IV

Clay No. 4. Cretaceous shale, Springfield, Minnesota.[1] Used for hollow brick and tile.

		Fractions				
	Whole clay	Coarse sand 4.0%	Fine sand 16.0%	Silt 76.8%	Coarse clay 2.1%	Fine clay 1.1%
Silica	64.08	65.	62.16	67.84	44.9	33.
Alumina	17.48	1.7	16.12	14.54	22.2	18.
Iron oxides	5.03		6.16	4.80	6.3	5.
Magnesia	1.42	1.	.51	.82	2.6	4.
Lime	1.00	3.	1.76	.96	4.0	10.
Soda	.20	N. d.	1.81(?)	.14	N. d.	N. d.
Potash	1.74	N. d.	1.34	1.70	N. d.	N. d.
Ignition	7.12	14.	7.80	6.78	16.0	20.
Moisture	1.00	N. d.	1.40	.56	1.3	6.
Titania	1.19	N. d.	1.07	1.22	1.2	1.
	100.26		100.13	99.36		
Fluxes	*9.5*	*9.+*	*11.6*	*8.4*	*13.+*	*19.+*

Sands show quartz, black sand, and shale lumps.

Clay contains some carbonaceous matter.

[1] This is a clay bank on the other side of Springfield from that of which analysis is given in U. S. Geol. Surv., *Bull.* **678**, p. 134.

subtracted from the loss on ignition. Each table reports as "fluxes" the sum of the oxides of iron, magnesium, calcium, sodium and potassium.

TABLE V

Clay No. 5. Residual clay from biotite schist, Bowlus, Minnesota. Not used.

		Fractions				
	Whole clay[1]	Coarse sand 18.5%	Fine sand 41.7%	Silt 38.7%	Coarse clay 1.0%	Fine clay .1%
Silica	57.20	36.70	65.12	56.06	40.	....
Alumina	18.23	35.41	14.59	21.80	17.	....
Ferric oxide	5.45	8.22	4.71	7.41	12.	....
Ferrous oxide	5.03	8.14	3.61			....
Magnesia	1.02	1.89	1.00	1.43	4.	....
Lime	.72	.24	.16	.43	5.	....
Soda	.61	1.23	.46	.94	N. d.	....
Potash	.98	1.37	.68	.86	N. d.	....
Ignition	8.20	6.38	8.58	9.62	18.	....
Moisture	.24	.00	.36	.92	1.	....
Titania	1.52	.97	1.21	1.21	1.	....
	99.20	100.55	100.48	100.68		
Fluxes	*13.8*	*21.1*	*10.6*	*11.1*	*21.*	

Sands show staurolite, chlorite and quartz.

[1] Modified from that published in U. S. Geol. Surv., *Bull.* **678,** to show *ferrous* iron, and corrected amounts of moisture and combined water.

TABLE VI

Clay No. 6. Red glacial drift, Coon Creek, Minnesota. After passing rolls, used for medium vitrified brick.

		Fractions				
	Whole clay	Coarse sand 5.5%	Fine sand 5.1%	Silt 47.5%	Coarse clay 24.6%	Fine clay 17.3%
Silica	60.49	67.57	86.04	64.94	53.06	46.70
Alumina	14.39[1]	15.53	6.90	12.46	19.85	25.26
Iron oxides	6.03[1]	4.00	1.28	3.97	5.39	6.34
Magnesia	3.68	2.12	1.23	4.26	5.34	2.56
Lime	3.87	3.34	1.90	3.40	3.28	3.04
Soda	2.17	2.20	.69	2.04	1.10	2.06
Potash	2.53	1.20	1.37	2.43	2.32	1.92
Ignition	5.90	2.40	.82	4.98	7.61	7.72
Moisture	1.94	.34	.02	.42	1.44	3.92
Titania	.42	1.67	.30	1.11	1.08	1.12
	101.42	100.37	100.55	100.01	100.47	100.64
Fluxes	*18.±*	*12.9*	*6.5*	*16.1*	*17.4*	*15.9*

[1] Corrected from the results shown in U. S. G. S., *Bull.* **678.**

Sands show quartz and trap rock.

Clays somewhat scaly as if colloidal.

TABLE VII

Clay No. 7. Glacial laminated clay from red drift, St. Croix River, Pine County, Minnesota. Not now used.

				Fractions		
	Whole clay[1]	Coarse sand trace	Fine sand .3%	Silt 42.0%	Coarse clay 29.7%	Fine clay 28.0%
Silica	56.85	....	76.0	63.38	54.14	47.00
Alumina	14.87	....	13.0	13.45	17.58	18.16
Iron oxides	7.40	....	3.0	4.81	8.14	10.88
Magnesia	4.49	....	1.0	3.46	4.50	5.32
Lime	3.58	....	2.0	4.08	.2.44	2.24
Soda	1.31	....	N. d.	1.58	.96	1.22
Potash	2.39	....	N .d.	2.81	2.90	2.88
Ignition	6.60	....	2.5	5.16	7.86	7.08
Moisture	1.80	....	.5	1.14	.34	3.92
Titania	.55	....	.5	.54	.68	.92
	99.84	....		100.41	99.54	99.62
Fluxes	*19.2*	....	*6.+*	*16.7*	*18.9*	*22.5*

Clay lumps had to be rubbed to break them up. More rubbing might have increased the per cent of fine clay. Clays slightly colloidal.

[1] Not the same sample as the one reported in U. S. G. S., *Bull.* **678,** p. 215.

TABLE VIII

Clay No. 8. Glacial laminated clay from gray drift, North Minneapolis, Minnesota. Used for cream brick and fire proofing.

				Fractions		
	Whole clay	Coarse sand trace	Fine sand .5%	Silt 79.5%	Coarse clay 10.9%	Fine clay 9.1%
Silica	50.65	....	73.2	50.22	44.76	44.66
Alumina	10.25	....	10.3	9.81	14.34	17.21
Iron oxides	4.00	....	.6	3.03	5.08	7.09
Magnesia	4.68	....	2.0	5.77	4.30	2.88
Lime	10.65	....	4.6	12.36	9.88	6.56
Soda	1.44	....	N. d.	1.02	1.30	1.30
Potash	1.96	....	N. d.	1.51	2.15	2.36
Ignition	2.10	....	5.0	1.96	3.92	5.31
Carbon dioxide	12.30	....	.5	13.60	11.50	7.98
Moisture	1.20	....		.44	2.22	3.76
Titania	.52	....	.2	.55	.34	.92
	99.75	....		100.27	99.79	100.03
Fluxes	*22.7*	....	*7.2*	*23.7*	*22.7*	*20.2*

Sand shows mostly quartz, but a little magnetite, orthoclase, hornblende, calcite, and mica. Clays formed a crust or scale as if largely colloidal.

TABLE IX

Clay No. 9. Loess clay, Preston, Minnesota. Used for building brick (and in foundry sands).

	Whole clay[1]	Fractions: Coarse sand .1%	Fine sand .9%	Silt 84.3%	Coarse clay 8.5%	Fine clay 6.2%
Silica	70.50	58.	67.7	74.80	51.28	46.48
Alumina	12.28	N. d.	9.5	11.36	19.06	23.86
Iron oxides	4.06	N. d.	5.3	3.10	7.84	7.96
Magnesia	1.81	15.(?)	2.8	1.42	2.47	2.77
Lime	1.27	8.(?)	2.1	1.78	1.82	1.20
Soda	1.73	N. d.	.1	1.39	.61	.58
Potash	1.95	N. d.	3.7	2.22	1.40	1.07
Ignition	3.88	10.	6.9	2.80	10.10	12.00
Moisture	1.92	1.	1.5	.46	4.28	4.18
Titania	.34	N. d.	.5	.68	.92	.32
	99.74		100.1	100.01	99.78	100.42
Fluxes	*10.8*	*23.±*	*14.0*	*9.9*	*14.1*	*13.6*

Sands show quartz, limonite, and mica.
Clays formed scale as if largely colloidal.

[1] Not the same sample as the one analysed in U. S. G. S., *Bull.* **678,** p. 160.

TABLE X

Clay No. 10. Lake clay, Heron Lake, Minnesota. Used for hollow brick and drain tile.

	Whole clay	Fractions: Coarse sand .4%	Fine sand 4.1%	Silt 69.4%	Coarse clay 16.8%	Fine clay 9.3%
Silica	53.94	60.	81.4	56.28	42.42	42.46
Alumina	11.39	19.	7.0	10.80	14.55	19.93
Iron oxides	3.29		1.0	2.24	6.11	10.22
Magnesia	3.47	8.	.8	3.77	2.71	2.90
Lime	9.80	4.	4.5	10.22	12.22	4.87
Soda	2.34	N. d.	N. d.	1.46	1.73	1.45
Potash	.76	N. d.	N. d.	1.35	.99	.92
Ignition[1]	4.16	4.	2.1	3.00	5.58	9.32
Carbon dioxide	8.62	N. d.	N. d.	9.38	10.68	2.42
Moisture	1.64	2.	.3	.90	2.72	5.28
Titania	.65	N. d.	.2	1.00	.84	.65
	100.06			100.40	100.55	100.42
Fluxes	*19.7*	*18.−*	*6.+*	*19.0*	*23.8*	*20.4*

Sands show mostly quartz, with traces of limonite.
Clays formed scale as if largely colloidal.

[1] Carbon dioxide where estimated is subtracted from total loss on ignition.

TABLE XI

Clay No. 11. Swamp clay, Tower, Minnesota. Used without much success for building brick.

	Whole clay	Fractions: Coarse sand 4.0%	Fine sand 18.1%	Silt 73.3%	Coarse clay 3.1%	Fine clay 1.5%
Silica	52.92	58.78	48.92	50.52	43.4	1.
Alumina	16.73[1]	16.00	18.16	16.88	19.1	1.
Iron oxides	4.98[1]	4.16	4.90	4.93	8.1	N. d.
Magnesia	3.78	2.96	3.68	6.73	7.0	5.
Lime	5.95	4.95	6.64	5.88	5.7	25.
Soda	.97	2.42	.70	1.45	N. d.	N. d.
Potash	2.32	2.89	3.36	2.90	N. d.	N. d.
Ignition	8.85	6.75	11.60	8.40	11.1	22.
Moisture	3.33	1.12	2.10	2.06	.4	
Titania	.52	.52	.56	.61	.7	N. d.
Sulphuric oxide	....	....	....	....	....	44.
	100.35	100.55	100.62	100.36		
Fluxes	*18.0*	*17.4*	*19.3*	*21.9*	*21.+*	*30.+*

Coarser sizes are clay lumps not broken by a rubber pestle.
The "fine clay" is mostly soluble salts, gypsum.

[1] Corrected from the results published in U. S. G. S., *Bull.* **678.**

TABLE XII

Clay No. 12. River clay as recently deposited by the Minnesota River at Le Sueur, Minnesota. Used for red brick.

	Whole clay	Fractions: Coarse sand 4.1%	Fine sand 25.7%	Silt 58.5%	Coarse clay 6.0%	Fine clay 5.5%
Silica	62.20	52.0	64.50	61.60	50.90	42.24
Alumina	7.77	9.0	8.12	8.33	14.31	13.82
Iron oxides	4.53	5.3	4.15	2.89	8.19	7.03
Magnesia	3.18	3.5	2.06	4.23	2.69	1.66
Lime	7.21	8.8	7.40	8.30	4.10	9.10
Soda	3.58	2.4	2.10	2.27	2.02	1.22
Potash	1.63	1.1	2.12	1.73	1.90	3.42
Ignition	9.27	13.7	8.30	11.52	11.78	15.82
Moisture	2.15	2.9	.30	.20	3.96	4.90
Titania	.41	.6	.37	.50	.60	.69
	101.93	100.1	99.42	101.57	100.45	99.90
Fluxes	*20.1*	*21.1*	*17.8*	*19.4*	*18.9*	*22.4*

Sands show fragments of wood, shells, quartz, and lumps of shale and other rocks.
Clay seems oily rather than colloidal.

TABLE XIII

SUMMARY OF THE RELATION OF TEXTURE TO COMPOSITION IN TWELVE MINNESOTA CLAYS

		Coarse sands	Fine sands	Silts	Coarse clay	Fine clay
Silica	Av.	54.83	71.15	61.29	48.07	40.61
	Max.	67.57	91.28	79.16	54.14	50.30
	Min.	36.70	48.92	50.22	40.00	1.00[1]
Alumina	Av.	13.02	10.16	13.30	18.83	18.97
	Max.	35.41	18.16	21.80	29.24	32.96
	Min.	1.7	.77	8.33	14.31	1.00[1]
Iron oxides	Av.	11.65	3.72	3.94	6.91	7.42
	Max.	47.4	8.32	7.41	12.00	10.88
	Min.	1.8	.60	1.68	2.46	2.62
Magnesia	Av.	4.19	1.66	3.31	3.56	3.19
	Max.	15.00	3.68	6.73	7.00	5.32
	Min.	.40	.51	.82	1.16	1.66
Lime	Av.	5.93	3.65	5.11	4.96	6.24
	Max.	14.40	7.40	12.36	12.22	25.00[1]
	Min.	.24	.16	.43	.96	1.04
Soda	Av.	1.63	.86	1.32	1.17	1.19
	Max.	2.42	2.10	2.27	2.02	2.06
	Min.	.20	.10	.04	.61	.58
Potash	Av.	2.17	2.20	2.33	2.57	2.62
	Max.	4.80	4.90	6.90	6.62	6.70
	Min.	1.10	.68	.86	.99	.92
Ignition	Av.	8.62	5.08	7.05	10.91	12.51
	Max.	14.00	11.60	15.56	18.00	22.00
	Min.	2.40	.82	2.12	4.90	5.94
Titania	Av.	.69	.50	.85	.89	.79
	Max.	1.67	1.21	1.49	1.46	1.12
	Min.	.18	trace	.50	.34	.32
Fluxes	*Average*	*25.6*	*14.1*	*15.9*	*19.2*	*20.7*

[1] Soluble salts.

TABLE XIV

ANALYSES OF WEST VIRGINIA CLAYS SEPARATED BY MECHANICAL METHOD[1]

	Coarse sands	Fine sands	Silts	Coarse clay	Fine clay
Silica	76.63	81.16	70.30	54.54	44.08
Alumina	13.01	9.76	16.04	23.00	28.16
Iron oxides	4.89	2.53	3.84	6.90	8.93
Magnesia	.48	.39	.80	1.02	1.36
Lime	.47	.31	.72	.82	.76
Soda	.00	.56	.45	.29	.00
Potash	.93	1.78	2.14	3.31	3.05
Moisture	.87	.35	.56	1.10	2.80
Ignition	4.40	2.59	4.33	7.79	10.86
Titania	.60	.78	1.08	1.12	.84

[1] Frank F. Grout, W. Va. Geol. Surv., **3**, 60–62 (1906).

The writer's work on West Virginia clays is here copied because it corroborates the general conclusions drawn from the Summary Table of Minnesota clays. The separates of different grades of fineness from some sixteen samples of clay were analyzed, with the results shown in the following table. The sizes of grain in each separate correspond to those in the Minnesota samples. These clays have a much lower per cent of fluxes than the average Minnesota clays, but the variation with texture is in the same direction.

Distribution of Elements by Sizes of Grain

The prevailing ideas on this subject of concentration of certain elements in certain sizes of grain have been developed from scant data. Steinkoenig's data for soils[1] and the writer's report based on West Virginia clays[2] can now be somewhat corrected.

Silica is the most abundant oxide in all cases (except the rare "fine clay" with more soluble salt than sediment). The silica, however, is rarely at a maximum in the coarsest size as was supposed. The averages show clearly, as nearly all the individual samples do, that silica tends to concentrate in the fine sand .05 to .5 mm. Coarser particles usually represent unaltered rock fragments with many minerals, or concretions of other minerals than quartz; but the fine sands are the residues of quartz from the well-leached and transported altered rock.

Alumina shows a steady variation to the maximum in fine clay, but a few coarse sands are rich in aluminous minerals such as feldspar and staurolite, and even lumps of shale.

Iron oxides similarly increase from sand to the finest sizes. The high iron content of coarse sand in the Minnesota average, is largely a consequence of a single sample in which limonite concretions are abundant. They are coarse enough to be washed out commercially. Nevertheless the tendency of iron to be high both in the coarsest and finest, is shown by the results of all the work.

Potash averages show a clear tendency to be at a maximum in the finer sizes and most individual samples confirm the conclusion. Exceptions result from occasional coarse feldspars.

Phosphorus is reported by Steinkoenig as most abundant in the smallest grains.

Combined water is at a maximum in the fine clays and is important in the sands only when limonite or shale lumps appear in those fractions.

There are a few cases where the sum of all the "*fluxing ingredients*" is about the same in each of the analyzed fractions as it is in the whole clay.

[1] L. A. Steinkoenig, *loc. cit.*

[2] Frank F. Grout, W. Va. Geol. Survey, *loc. cit.*

See Nos. 1, 3 and 12. In a much larger number, the "total fluxes" are a larger per cent of the fine fractions than of the coarse. This is probably related to the increase in iron and potash.

This tendency for fluxes to increase led the writer to remark that "the finest sizes are not the purest kaolin." This was possibly incorrect, or at least a poor way to say that the finest sizes are more contaminated with fluxing impurities. Purdy made some calculations to show that kaolinite is concentrated in the fine clays, along with the concentration of fluxes.[1] The decrease in silica allows an increase of both kaolinite and iron and potash.

Lime, magnesia, soda and titanium vary erratically. Lime as fossils and concretions tends to the coarser fraction, but as a mechanical sediment it is often as fine as silt and may be abundant in the clay sizes. Magnesia in dolomite may behave similarly, but as a silicate, more or less hydrous, its behavior is erratic. It shows a slight tendency to be more abundant in the finer sizes. Soda seems wholly erratic in its behavior, possibly in part due to inaccuracy and incompleteness in the chemical work. Titanium is well distributed in all sizes.

Distribution of Elements by Sizes, in Clays of Different Origin

A study of the exceptions to the general rules just given is instructive geologically. It is the residual clay that shows alumina and iron at a maximum in the coarse sand. This is the exceptional case where alumina and iron were present in two minerals—primary chlorite as well as the usual clay minerals.

Another exception to the rule of greater iron content in the finer clays is found in shales that have been subject to concretionary action. In one case limonite and in another pyrite has developed into such masses as to appear in the coarse sand.

If allowance is made for these two types of deposit (residual clay and shale with concretions), there is even a stronger tendency for all clays to fall into simple series; silica at a maximum in fine sands; alumina, iron oxides, potash, and to some extent magnesia showing larger amounts in the finer sizes.

Textures of Clays of Different Origin

The textures of clays studied in Minnesota are fairly represented by this set of mechanical analyses. While the differences are more or less related to mode of formation of the deposit, it may be too early to attempt to give very definite criteria by which origin can be judged from texture.

[1] R. C. Purdy, "Pyrophysical and Chemical Properties of Paving Brick Clays," Ill. Geol. Surv., *Bull.* **9**, 180–186 (1908).

It should be emphasized, also, that data are limited to clays, not covering the broader field of sediments in general. The noteworthy features are as follows:

The "clay substance" (grains less than .005 mm. in diameter), constitutes a surprisingly small proportion of these clays. Silt is the most abundant fraction. Clays deposited in quiet water have practically no sand, while glacial and residual clays have much. The wind blown loess is especially well sorted, practically all grains being of silt size.[1]

The Minerals of Fine Clay

The usual list of minerals of clays includes kaolinite and those visible in coarser particles. The estimates of other fine-grained minerals are few and need critical review. Microscopic identification is very difficult. The assumption at the basis of a rational analysis is not satisfactory for complex mixtures such as are here studied.

Some few fine clays have so nearly the composition of kaolinite that it is commonly assumed to be present. Most good kaolins, however, are coarser than the "clay fractions" in a mechanical analysis; and a large number of fine clays have not the composition of kaolinite, so that the assumption of the presence of kaolinite is not entirely safe.

Van Hise suggests that some of the water is combined in hydrous minerals such as *zeolites*.[2] Hutchings found that while feldspar (and biotite, chlorite and clastic muscovite) was absent from the fine parts of carboniferous shales, a new micaceous mineral could be detected.[3] Leith and Mead report that shales in general may have chlorite, serpentine and talc, but are more likely to give oxides, carbonates and hydrates; also that potash may be present as sericite, but likely also adsorbed or combined with the finer or colloidal material.[4] They calculate the percentage of such minerals from the average composition of shales. (See Table XV.)

Purdy has made some calculations on the analyses of fine clay in the attempt to determine whether kaolinite is actually present in it.[5] He notes as Merrill has,[6] that the method of mechanical analysis by which fine clays are separated for chemical tests, leaves with the finest fraction nearly all the soluble salts, and the potash or other salts adsorbed by colloids. See clay No. 11, in this work as an extreme case, in which gypsum constituted most of that fraction.

[1] This was noted in wind blown sands by M. I. Goldman, "The Petrography and Genesis of Sediments," Maryland Geol. Surv. (1916).

[2] C. R. Van Hise, "Treatise on Metamorphism," U. S. Geol. Surv., *Mon.* **47,** p. 893.

[3] W. M. Hutchings, "Clays, Shales and Slates." *Geol. Mag.*, **33,** 310 (1896).

[4] Leith and Mead, *op. cit.*, pp. 77, 78 and 88.

[5] R. C. Purdy, "Qualities of Clays Suitable for Making Paving Bricks," Ill. Geol. Surv., *Bull.* **9,** 182–185 (1908).

[6] *Op. cit.*, pp. 121 and 365.

Still other results have been obtained showing a further difficulty in any attempt to calculate these minerals. The fine clays with particles less than .001 mm. in diameter have no doubt some particles so fine that they are no longer properly minerals but colloidal solutions or gels, with a variety of adsorbed salts. The United States Bureau of Soils has a fairly conclusive demonstration that soils contain inorganic as well as organic colloids such as have long been suspected in clays. These have been isolated and appear to be essentially silicates of iron and aluminum; the small amounts of lime, magnesia, potash and soda may or may not be parts of the colloid.[1]

With so many disturbing factors it may be doubted whether satisfactory mineral diagnosis can be made of the finest clays, but the abundance of fine clays in some deposits makes it desirable to assemble what information is available and make the best estimate possible. It is possible that further studies of mineral solubilities may make an approximate mineral (rational) analysis possible at some future day. Such a method would have to estimate at least eight or ten minerals rather than the three now reported in rational analyses.[2]

An attempt was made to calculate the mineral composition of the silt and clay fractions of the twelve Minnesota clays and Table XV shows the result. The method is open to criticism, but it is hoped that the approximation may be of some interest.

TABLE XV

COMPARISON OF THE CALCULATED MINERALS OF THE AVERAGES OF FINER FRACTIONS FROM MECHANICAL ANALYSES OF TWELVE MINNESOTA CLAYS

	Silt, per cent	Coarse clay, per cent	Fine clay, per cent	Average shale; estimate by Leith and Mead, per cent
Kaolinite and "clay minerals"	7.5	17.0	23.2	10
Sericite and paragonite	16.6	21.2	22.1	18
Quartz	36.7	19.3	13.1	32
Chlorite and serpentine	8.2	10.3	7.3	6
Limonite, hematite (and pyrite)	3.0	5.5	8.0	5
Calcite and dolomite	10.5	7.5	5.7	8
Feldspars	12.6	7.2	7.3	18
Zeolites	3.0	7.5	6.9	..
Titanite and rutile	1.7	2.0	1.7	1
Carbonaceous matter	.2	.9	.6	1
Moisture	.9	1.3	4.1	..

While there is a wide variation in the several samples, the trend is in most cases much the same as in the average, *viz.*, kaolinite and limonite

[1] Milton Whitney, "Fundamental Principles Established by Recent Soil Investigations," *Science*, **54**, 350 (1921).

[2] H. Ries, suggested such a possibility, emphasizing micas in his paper on, "The Rational Composition of Clays," *Trans. Amer. Ceram. Soc.*, **9**, 762 (1907).

are larger, and quartz and carbonates smaller as the grain is finer. Others are less regular.

The whole clays used in this study have an average composition close to average shale, but the fine clay differs a little from either average, having more kaolinite, zeolite and limonite, but less quartz, carbonate and feldspar.

The Amount of Kaolinite in Clays

Based on such assumptions, the calculated kaolinite in the "clay fractions" of twelve Minnesota clays averages about 20%, ranging from 4% to 53%. It would probably be useless to suggest that any ordinary clay had *no* kaolinite. Purdy has calculated that all grades of sizes of clay have kaolinite[1] and in this he is probably right. Some very plastic samples, however, have much less than 10% of kaolinite by calculation.

Thus if shale No. 3 has potash in mineral combination its content of kaolinite must be very small, around 5%. In several cases the kaolinite content would be doubled if most of the potash is considered adsorbed instead of combined, but it is perhaps most probable that only a part of the potash is adsorbed, and at least in the shales it is held so firmly that it is more likely in the form of sericite.

Again, clay No. 7 is so plastic and has so little kaolinite that one is tempted to suggest the presence of nontronite, the ferric kaolinite, instead of iron oxides, to explain its plasticity.

Finally, whether these assumptions are approved or not, the data indicate what has occasionally been noted before, that clay should not be defined so as to give an impression that it is over half kaolinite. Clay is not dominantly or essentially kaolinite in that sense.

Petrographic Applications

Geologists are frequently called upon to correlate the origin and the mineral nature of clay beds. In estimating the minerals of shale in the absence of all data, the calculation of Leith and Mead (Table XV) is the best guide. In case the field occurrence is known or a sample is available, the estimate may be much improved. Residual clays, glacial clays and loess, and water laid clays have each some mineralogical peculiarities.[2] The physical properties may be tested with additional evidence of minerals. Finally, the presence of certain minerals in the coarser fractions may be combined with the tendencies shown in Table XV to make the best estimate now possible, short of a calculation from analysis.

Relation of Fluxes to Fusibility

It has long been understood that in general an increase in the amount of certain impurities in kaolinite makes it less refractory. Attempts

[1] Purdy, *op. cit.*, pp. 203–204.

[2] Summarized by Clarke in U. S. Geol. Surv., *Bull.* **695**, pp. 499–510.

have been made to assign definite fluxing power to oxides of iron, magnesium, calcium, sodium and potassium, found by chemical analysis.[1] Several formulas for estimating refractoriness have been proposed.[2] It is not intended here to extend that work or propose any new formula, but simply to call attention to the nature of the clays that seem to show a fusibility different from that which would be expected from the amount of fluxes present.

TABLE XVI

	The distribution of fluxes of the whole clays through the several fractions					Comparison of total fluxes and temperatures of viscosity	
	In coarse sand, per cent	In fine sand, per cent	In silt, per cent	In coarse clay, per cent	In fine clay, per cent	Total fluxes, per cent	Temperature of viscosity, °F
1	4.0	3.0	9.5	3.0	1.5	21	2174
2	0.5	0.4	2.2	1.0	2.0	6	2426
3	0.2	0.2	8.0	2.4	7.5	18	2174
4	0.4	2.0	6.3	0.2	0.2	9	2166
5	3.9	4.4	4.7	0.2	trace	14	2345
6	0.7	0.3	8.0	4.4	2.5	18	2166
7	trace	trace	7.0	5.7	6.2	19	2102
8	trace	trace	18.8	2.3	2.0	23	2174
9	trace	0.1	8.3	1.2	1.0	11	2210
10	trace	trace	13.4	4.0	2.0	20	2138
11	0.6	3.4	15.9	0.5	0.2	19	2066
12	1.0	4.6	11.4	1.2	1.3	20	2174

Relation of Fineness to Fusibility

The diagram (Fig. 2) shows the relation between the amount of fluxes in these Minnesota clays and the temperature of viscous fusion. Of the twelve clays tested, two fall notably below the curve and two are high above.

The two clays, No. 5 and No. 8, with exceptionally high temperatures of viscosity, have their fluxes mostly in the sand and silt. Clay No. 1 has a tendency the same way.

On the contrary, clays No. 4, 7, 9, and 11 fuse at lower temperatures than average. Clay No. 7 has its fluxes in the fine portions where they might be expected to exert their full influence at low temperatures. Clays No. 4 and 11, however, seem to have no such abundance of fine fluxing matter. By reference to the tables, however, it will be seen that although the clay fraction is small in amount it has a composition high in fluxes. In other words, although these two samples have very little clay of the finest sizes, that small portion is very fusible.

[1] Richter's laws published in 1868, critically reviewed by Cramer in 1895, are valuable. See E. Cramer, *Tonindustrie Zeit.* (1895). Curves are given by R. C. Purdy in Ill. Geol. Surv., *Bull.* **9**, 207–210 (1908).

[2] H. A. Wheeler, "Clay Deposits," Mo. Geol. Surv., **11**, 143–153 (1896).

This raises the question whether the temperature of viscosity is most influenced by the *amount* of fine flux or by the *fusibility* of a small amount of fine flux.

Figure 1 is drawn to show the relation of temperatures of viscosity to the per cent of fluxes in the finest fraction of the clay. If this is compared with Fig. 2, it is easily seen that the several samples fall closer to the curve than the same samples plotted by the method of Fig. 2. This strongly confirms the suggestion that *the nature of the fine clay is of more influence than its amount*, so long as it constitutes a few per cent of the whole.

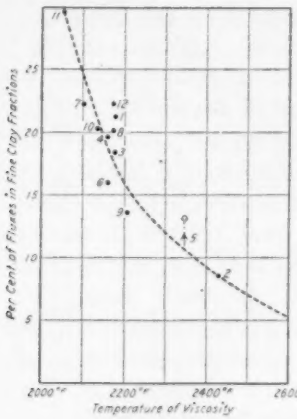

FIG. 1.

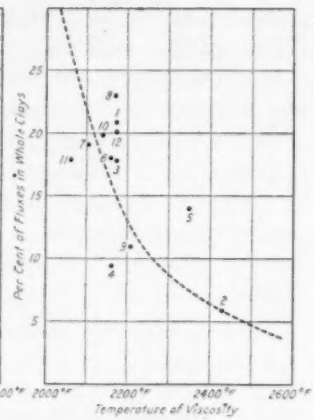

FIG. 2.

FIGS. 1 AND 2.—Curves of the relation between fluxes in clays and their temperatures of viscous fusion. Note first that the fusion points seem to be more uniformly close to the curve when plotted in relation to the per cent of fluxes in the finest fraction, (Fig. 1) than when in relation to the total fluxes of the whole clay (Fig. 2). Note further that in Fig. 2, clays falling above the curve, No. 1, 5, and 8, have fluxes mostly in the coarser fractions; while those below the curve, No. 4, 7, and 11, have little of their fluxes in the sand, Table XVI.

So far as the writer is aware, none of the formulas proposed for calculating fusibility take into account these two factors; the distribution of fluxes with size of grain, and the per cent of fluxes in the finest size. Since each has probably a definite effect, the formulas are necessarily inaccurate; but no accurate formula can be proposed without such an elaborate study that the fusibility can be much more readily determined by experiment than by calculation. The futility of attempts to calculate fusion from analysis is shown by a simple list of the factors which are known to modify the result but modify it to a wholly uncertain degree, *viz.* (1.) Average size of grain of the clay. (2.) The mineral combination of the oxides. (3.) The distribution of fluxes through the several sizes. (4.) The per cent of fluxes in the fine clay portion.

It is noteworthy that Wheeler's formula[1] which gives extra weight to alkalies as fluxing ingredients, while not justified by the experimental work of Richter, and of Cramer, may be somewhat justified by the tendency of potash to concentrate in the fine clay fraction as shown in tables above. Potash is doubly active in most clays, because it is not only a flux for the clay as a whole, but is most abundant in the fine clay, the fusibility of which is the most important factor in determining the viscosity of the mass.

Mixing Clays

Analyses of crude clays showing the proportion of fluxes can hardly be a safe guide as to the effect of the clay when used as a binder or admixture for other clays. Referring to Table XVI, clay No. 7 with most of the fluxes in coarse and fine *clay* fractions must certainly yield different results from clay No. 11 or No. 12 where the fluxes in the clay fractions are less than 2%, though all have about the same amount of fluxes in the crude clay.

Here again the dominance of *composition of fine clay* in control of viscosity may be suggested. If the fine clay portion of an added bond is of the correct fusibility, the coarse may be of considerable variety without much effect. This may be of great importance in determining the availability of a clay before more expensive practical tests are made in the kiln.

Beneficiation of Clays by Washing

Clays No. 1 and No. 2 are washed commercially. No. 1, the gray drift, is stirred up with excess of water in a pit. A bucket elevator of

TABLE XVII

CLAY NO. 1 AND ITS COMMERCIALLY WASHED FRACTIONS

		Clay artificially settled after removal of gravel			
	Whole clay	Sand near intake	Sand near center	Clay near center	Clay far from intake
Silica	58.85	70.21	62.60	50.65	50.55
Alumina	7.25	6.27	6.96	9.01	9.41
Iron oxides	4.97	3.16	3.75	5.26	6.19
Magnesia	3.45	1.55	3.59	3.60	3.62
Lime	9.42	7.28	7.78	10.20	10.20
Soda	1.37	2.11	1.94	1.32	1.22
Potash	1.76	1.53	1.82	1.83	1.85
Ignition	2.10	1.38	2.90	6.10	6.05
Moisture	2.10	.60	1.80	3.40	3.10
Titania	.36	.19	.33	.53	.60
Carbon dioxide	9.10	6.00	7.10	8.20	8.00
	100.73	100.28	100.57	100.10	100.79

[1] *Op. cit.*

continuous operation dips into the pit near the center, and removes the gravel. At the side of the pit a screen allows the sand and clay to escape into settling ponds, where some of the water can be pumped off and some settles into the ground. The sand settles mostly near the intake and the clay is carried to the farther side. The samples from several parts of such an artificial deposit show general concordance with the laboratory washing.

Clay No. 2 is a stoneware clay washed commercially by a very different process. The crude clay is reduced to a slush and the sand removed in rotary sieves (80-mesh), after which the clay goes to large filter presses. The commercial separation yields a purified product resembling a mixture of the silt and clay portions of the mechanical analysis. The analyses of the sand of the laboratory separation and the refuse of the commercial washing agree perfectly in showing that the improvement results from a removal of iron oxide concretions and quartz.

TABLE XVIII

CLAY NO. 2 AND ITS COMMERCIALLY SEPARATED FRACTIONS

	Whole clay	Washed clay	Refuse from washing
Silica	69.92	69.26	64.98
Alumina	17.39	18.57	11.38
Iron oxides	1.68	1.93	12.03
Magnesia	1.11	.62	2.51
Lime	.60	.45	.68
Soda	.07	.06	.00
Potash	2.25	2.41	1.93
Ignition	5.45	5.58	5.28
Moisture	1.10	1.10	1.08
Titania	.63	.77	.71
	100.20	100.75	100.58

It may be said without much possibility of question that the improvement in both these clays, and the nature of the improvement, could have been foretold from a laboratory study of the chemistry of the fractions separated in a mechanical analysis. It may easily happen that such a study will save a large investment in experimental washing plants.

STATE GEOLOGIST
MINNEAPOLIS, MINN.

THE DEAD BURNING OF DOLOMITE—II[1]

By James Thomas Robson and James R. Withrow

Preliminary Investigation

There are many large deposits of dolomite in the United States. These range from the very pure dolomite of Ohio and the eastern states, notably New York and Pennsylvania which correspond very closely to the theoretical formula $CaCO_3$ $MgCO_3$ to dolomites which are very low in MgO content.

Throughout this work, a pure variety of dolomite obtained from the Niagara deposit at Cedarville, Ohio, was used.

It analyzed as follows:

Silica (SiO_2).....	0.4	Potassium oxide (K_2O)...	trace
Aluminum oxide (Al_2O_3)..	0.5	Sodium oxide (Na_2O).....	trace
Ferric oxide (Fe_2O_3).....	0.5	Sulfur trioxide (SO_3).....	none
Calcium oxide (CaO)....	30.2	Carbon dioxide (CO_2)....	46.8
Magnesium oxide (MgO).	21.8		100.2

The true specific gravity of this dolomite is 2.85.

This dolomite was crushed in jaw crushers, then ground through rolls and finally ground in the dry pan until it all passed 100 mesh, which Schurecht[2] found to be the best degree of fineness. After the entire batch had been screened, it was again thoroughly mixed for about 15 minutes in a dry pan so that the harder material was evenly distributed throughout the softer material which passed through the screen first.

Series 1A

The pulverized dolomite was then mixed with Al_2O_3, Fe_2O_3 and SiO_2 in the proportion of 90% dolomite by weight to 10% of flux by weight maintaining the 90% of dolomite constant and blending the 10% of fluxes in a three variable series consisting of twenty-two members apportioned as follows:

Number	Fe_2O_3	Al_2O_3	SiO_2	Number	Fe_2O_3	Al_2O_3	SiO_2
1A1	10	..	..	12	2	8	..
2	8	2	..	13	2	6	2
3	8	..	2	14	2	4	4
4	6	4	..	15	2	2	6
5	6	2	2	16	2	..	8
6	6	..	4	17	..	10	..
7	4	6	..	18	..	8	2
8	4	4	2	19	..	6	4
9	4	2	4	20	..	4	6
10	4	..	6	21	..	2	8
11	3.33	3.33	3.33	22	..	..	10

[1] The first paper in this series appeared in *Jour. Amer. Ceram. Soc.*, **7** [1], 61(1924).

[2] *Jour. Amer. Ceram. Soc.*, **4** [2], 133(1921).

J. T. Baker's analyzed alumina and ferric oxide, also flint obtained from the Pennsylvania Pulverizing Co., were used as fluxes. These analyzed as follows:

Alumina		Ferric oxide		Flint	
Al_2O_3.....	99.99%	Fe_2O_3.....	99.99%	SiO_2.....	99.81%
SiO_2.....	0.001%	FeO.....	trace	Al_2O_3.....	0.17%
Fe.....	.005%	SO_3.....	0.007%	Fe_2O_3.....	0.014%
CaO.....	.001%			CaO.....	none
Cl.....	.001%			MgO.....	none
SO_3.....	.001%				

These analyses were made on the samples after drying at 105°C. The amount of moisture present in each was as follows:

Alumina	Ferric oxide	Flint	Dolomite
0.24%	0.32%	0.07%	0.11%

Moisture

In all compositions, corrections were made for moisture, *e. g.*, a 3200 gram batch of member 1A calls for 2880 grams of dolomite (=90%) and 320 grams of iron oxide (=10%). The amount of moisture in the dolomite is 0.11%, therefore $\frac{2880}{(100-0.11)} \times 100 = 2883.2$ grams of dolomite required. The moisture in the iron ore is 0.32%, hence $320 \div (100-0.32) \times 100 = 321.03$ grams of iron ore were added to 2883.2 grams of dolomite giving a 90% dolomite and 10% ferric oxide mixture.

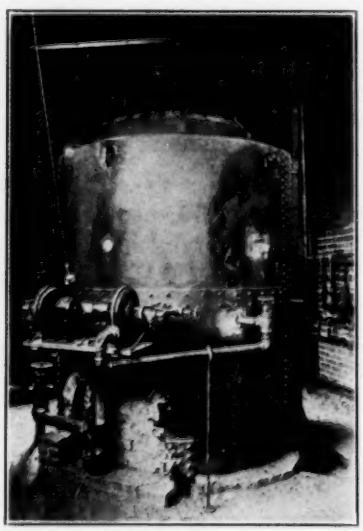

FIG. 11.—Gas fired kiln.

The end members 1A1, 1A17 and 1A22 were prepared by grinding the dolomite with the respective oxides in the dry pan for about one hour or until the added flux was thoroughly mixed throughout the dolomite as shown by a very uniform color. These end members were then blended, so as to produce the intermediate members by weighing out the proper quantity of each. Thoroughly mixing with a spatula, rolling back and forth on paper and screening through a 40-mesh screen twice. After this mixing which required about 20 minutes for each member of 400 grams, the blends were uniform in composition as shown by the uniformity of color in members where iron oxide was used.

One-inch cubes of the various mixtures were made by tempering the mix with water until it molded well. The average amount of water required was about 20% on the dry weight basis. The dry cubes were burned in a down-draft gas fired furnace shown in Fig. 11, to cone 16 down. The time for the burn was 54 hours. The temperature of burning as recorded by the pyrometer at 2-hour intervals is shown in Fig. 12. The curve is given to show the approximate rate of burning. Cones were placed throughout the kiln and all plaques of cones after the burn showed the heat to be evenly distributed throughout, that is, cone 16 down.

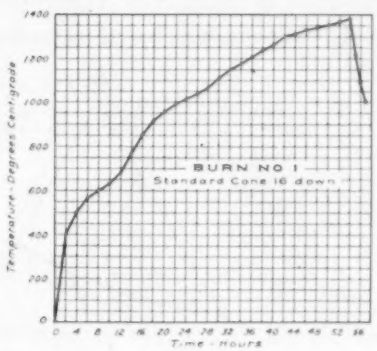

FIG. 12.

Burning Results of Series 1A

The colors of the burned cubes varied from black in the high iron oxide field to light brown in the alumina field to a pale green in the silica field. These colors are to be expected, the black due to the iron, the brown due to the alumina as in Portland cement clinker and the green similar to an ordinary lime silica slag. For colors of each member, see the following (Table I).

TABLE I

COLOR OF BURNED CUBES

Series 1A		Series B	
Member	Color	Member	Color
1–15	Black	1–16	Black
16	Dark brown	17	Brown
17	Light brown	18	Brownish green
18	Greenish brown	19–23	Green
19	Pale green	24	Yellowish green
20–21	Bluish green		
22	Yellowish green		

These cubes were set in the kiln on chrome powder spread over silica brick, to prevent fluxing between the dolomite and silica. Cubes of each member were also placed in the kiln on silica brick alone. Because of their strongly basic action, the cubes in contact with the silica fluxed partially down into the brick. Members 5, 6, 19 and 21 dusted down completely in the kiln when supported on silica brick. This was due to the formation of calcium orthosilicate and its consequent inversion from the beta to the gamma form as previously described in the introduction. This presence of the orthosilicate was confirmed by examination of some of the dust under the microscope. No cubes which were set on powdered chrome

completely disintegrated in the kiln; however, there was slight dusting on the bottom of all the cubes when they came in contact with the ore.

After removing the cubes from the kiln, the following properties were tested on separate cubes:

1. Air slaking resistance at room temperature.—Determined by allowing the cubes to stand in the laboratory and noting once per week the time at which they started to disintegrate or dust down.

2. Outside air slaking resistance.—Determined by allowing the cubes to stand outside on the window sill and noting when disintegration started.

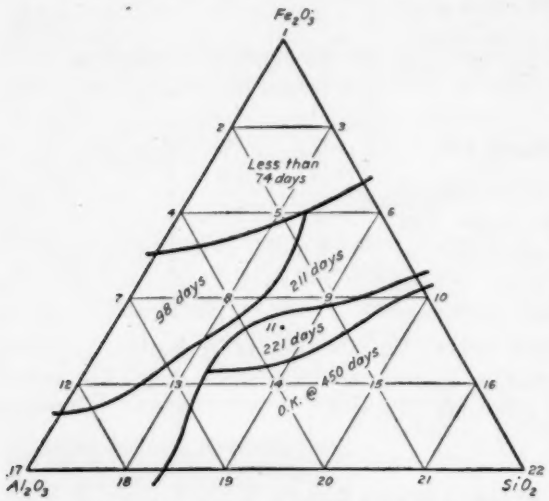

FIG. 13.—Room temperature air slaking test of series 1A.

3. Hot water test.—Cubes were placed in a pan of water and placed on the hot plate. The temperature of the water varied from 70–80°C. The water was renewed each day. Several times, due to fluctuation in the gas pressure, the water in the pan evaporated over night. In this case, without allowing the pan and its contents to cool, water directly from the faucet was run in on the hot cubes and the pan again placed on the hot plate.

Results of Tests on Series 1A

Room Temperature Air Slaking Test.—The results of the room temperature air slaking test are given in Table II and shown on Fig. 13. Here it is seen that the mixtures high in iron oxide are the least stable,

TABLE II

SERIES 1A

Air slaking test at room temperature

Cube no.	No. of days exposed before disintegrating	Order of slaking
1–5	71–73	First
7, 8 and 12	98	Second
6, 9, 13, 17 and 18	211	Third
11	221	Fourth
10, 14, 15, 16, 19, 20, 21, 22	Not slaked after 450 days' exposure	Fifth

Outside air slaking test

Cube no.	No. of days exposed before disintegrating	Order of slaking
1, 2 and 4	50	First
3	71	Second
5	92	Third
7, 8 and 12	106	Fourth
13, 17 and 18	149	Fifth
9 and 16	223	Sixth
6, 10, 11, 14, 15, 19, 20, 21, 22	Not slaked after 450 days' exposure	

Hot water slaking test

Cube no.	No. of days soaked before disintegrating	Order of slaking
1, 2, 3, 4, 5, 7, 8, 12 and 17	1	First
13 and 18	2	Second
16, 19, 21 and 22	5	Third
6 and 10	18	Fourth
9, 11, 15 and 20	50	Fifth
14	99	Sixth

whereas coming down toward the silica field, members 14, 15, 16, 19, 20, 21, and 22 have not yet disintegrated after 450 days' exposure, showing them to be very stable at room temperature when protected from the weather, so that it appears as though silica, 10% or less, stabilizes calcined dolomite with regard to slaking in the air.

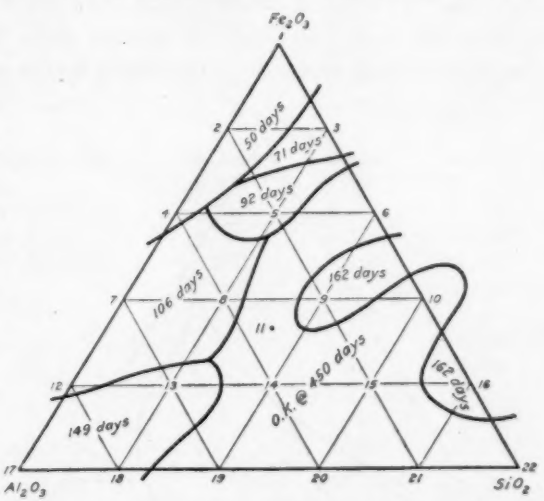

FIG. 14.—Outside air slaking test of series 1A.

Outside Air Slaking Test.—The results of this test shown in Table II and Fig. 14, follow somewhat according to the order of those obtained in the room temperature air slaking test, more accelerated in some cases and slower in others. Here again in general, the high iron region slaked down first, the high alumina region next. The middle region and that of the silica field are the most stable. As shown, these stable compositions have not slaked after 450 days' exposure in the air.

After about two weeks' exposure, all cubes were covered in places with a white coating which upon analysis proved to be $CaCO_3$. This lime was

no doubt due to free lime present in the cube combining with CO_2 from the air.

Two cubes of each member were tested here and in all cases those of the same composition disintegrated at the same time.

As mentioned, this test does not appear to be much different from the inside slaking test.

Hot Water Slaking Test.—For results of this test see Table II and Fig. 15. Here again, the region high in iron is the most unstable together with the members highest in alumina. In general, the field high in Al_2O_3 is more unstable than that in the silica field. However, the most stable field appears to be near the middle of the diagram, where all three oxides are present.

By far, the most stable composition in this series is member 1A14, whose composition is as follows:

Dolomite	90.0%
Fe_2O_3	2.0
Al_2O_3	4.0
SiO_2	4.0

This composition gives a formula as follows:

$$\left.\begin{matrix}0.5\ CaO\\0.5\ MgO\end{matrix}\right\}\ \left\{\begin{matrix}0.0399\ Al_2O_3\\.0128\ Fe_2O_3\end{matrix}\right\}\ 0.0685\ SiO_2.$$

In fact, this body 1A14 did not actually slake down. It simply cracked into three or four pieces after heating in warm water for 99 days. In the immediate field around 1A14 toward the SiO_2 corner as shown in Fig. 14, members 1A9, 1A11, 1A15 and 1A20 were the next most stable, withstanding this boiling test for 50 days before breaking down. These members like 1A14 simply cracked into 3 or 4 pieces and did not slake down into a powder as was the case with the more unstable compositions. This cracking may have been due to an expansion and contraction effect, since cold water was occasionally poured on the hot cubes as described in the method of procedure. It is

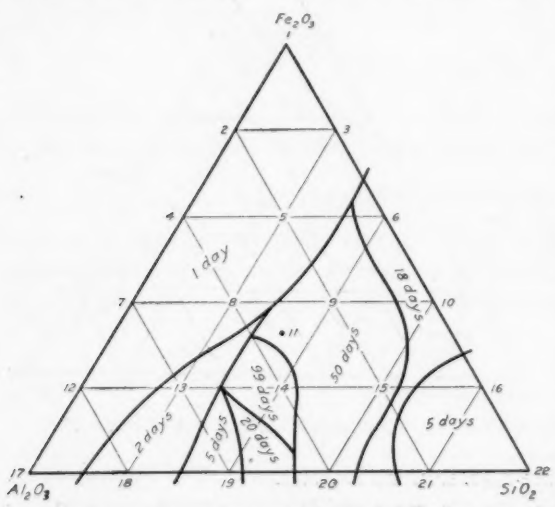

FIG. 15.—Warm water slaking test of series 1A.

thus seen that with this more severe and more accelerated test, the central field again proves to be the most stable, being more stable than the high silica field. In this test a considerable scum of $CaCO_3$ formed on the surface of the water in which the bodies were immersed.

Two cubes of each member were used in this test and again both slaked at the same time.

Series B

The next preliminary study was made in series B consisting of a twenty-four member series blending 90% of dolomite constant with 10% of variable fluxes blended on the molecular basis. The molecular ratios and corresponding percentage compositions by weight for this series are shown in Table III.

TABLE III

Member	Molecular ratio	Percentage composition Fe_2O_3	Al_2O_3	SiO_2
1	Fe_2O_3	10.0	...	...
2	$.8Fe_2O_3$ $.2Al_2O_3$	8.625	1.375	...
3	$.8Fe_2O_3$ $.2SiO_2$	9.140	...	0.860
4	$.6Fe_2O_3$ $.4Al_2O_3$	7.010	2.990	...
5	$.6Fe_2O_3$ $.2Al_2O_3$ $.2SiO_2$	7.475	1.590	0.935
6	$.6Fe_2O_3$ $.4SiO_2$	8.000	...	2.000
7	$.4Fe_2O_3$ $.6Al_2O_3$	4.730	5.270	...
8	$.4Fe_2O_3$ $.4Al_2O_3$ $.2SiO_2$	5.480	3.500	1.020
9	$.4Fe_2O_3$ $.2Al$ O_3 $.4SiO_2$	5.900	1.885	2.215
10	$.4Fe_2O_3$ $.6SiO_2$	6.400	...	3.600
11	$.33Fe_2O_3$ $.33Al_2O_3$ $.33SiO_2$	4.965	3.165	1.865
12	$.2Fe_2O_3$ $.8Al_2O_3$	2.820	7.180	...
13	$.2Fe_2O_3$ $.6Al_2O_3$ $.2SiO_2$	3.04	5.82	1.14
14	$.2Fe_2O_3$ $.4Al_2O_3$ $.4SiO_2$	3.300	4.220	2.480
15	$.2Fe_2O_3$ $.2Al_2O_3$ $.6SiO_2$	3.620	2.310	4.070
16	$.2Fe_2O_3$ $.8SiO_2$	4.000	...	6.000
17	Al_2O_3	...	10.00	...
18	$.8Al_2O_3$ $.2SiO_2$	...	8.720	1.280
19	$.6Al_2O_3$ $.4SiO_2$	...	7.180	2.820
20	Al_2O_3 SiO_2	...	6.300	3.700
21	$.4Al_2O_3$ $.6SiO_2$	...	5.320	4.680
22	Al_2O_3 $2SiO_2$	...	4.600	5.400
23	$.2Al_2O_3$ $.8SiO_2$	...	2.980	7.020
24	SiO_2	...	...	10.00

Member B20 contains Al_2O_3 and SiO_2 in the proportion in which they exist in sillimanite ($Al_2O_3 \cdot SiO_2$), while member B22 contains Al_2O_3 and SiO_2 in the same proportion as they exist in kaolin. These members were prepared in the same manner as those in series 1A, being made into cubes and burned with series 1A.

The members of this series were all burned on chromite powder. Because of lack of material only 3 cubes of each member were made.

Color

The cubes in general were the same color as in series 1A, *i. e.*, those containing Fe_2O_3 were black, Al_2O_3 gave a pale brown color and SiO_2 gave a green color. For colors of each member see Table I.

Results of Tests on Series B

Inside Air Slaking Test.—But one cube of each member was exposed to this test. The results are given in Table IV and Fig. 16. Here it is seen as likewise in series 1A, the unstable field is again toward that high in iron and the stable field toward the silica end of the diagram. In this series the very unstable iron field includes two more members, B4 and B6, than series 1A. However, the general slaking fields are very close to being the same, the more stable field again, being down toward the high silica region. Eight of the members as shown, are still stable after 450 days' exposure. It is noticeable that members 1A and B series, which have the same or nearly the same percentage composition by weight, also agree very closely in their air slaking resistance. These members are 1A3 and B6; 1A6 and B10; 1A10 and B16; 1A19 and B20. For example, 1A3 containing 8% Fe_2O_3 and 2% SiO_2 and B6 containing the same percentage of oxide both slaked after about 71 days exposure; 1A6 containing 6% Fe_2O_3 and 4% SiO_2 and B10 containing 6.4% Fe_2O_3 and 3.6% SiO_2 slaked after 211 days and 220 days, respectively. 1A10 and B16 having the same composition are still stable after 450 days' exposure. 1A19 containing 6.0% Al_2O_3 and 4.0% SiO_2 and B20 containing 6.3% Al_2O_3 and 3.7% SiO_2 are still stable after 450 days.

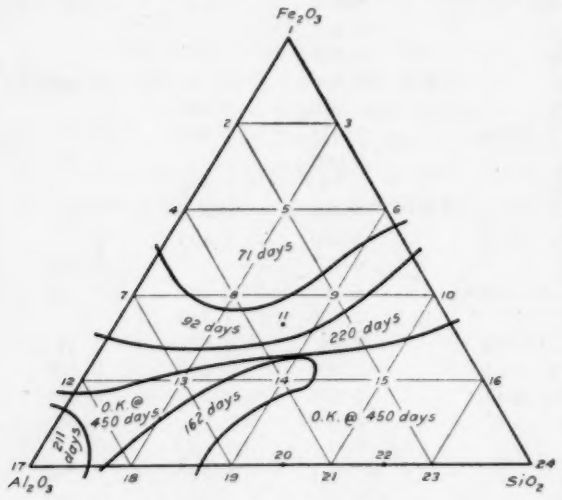

FIG. 16.—Room temperature air slaking test of series B.

Thus it appears that with 10% of flux and 90% of dolomite the percentage composition of the fluxes may be varied slightly among themselves

without making any very noticeable change in the air slaking resistance of the calcined mixture.

TABLE IV

SERIES B

Air slaking test at room temperature

Cube no.	No. of days exposed before disintegrating	Order of slaking
1, 2, 3, 4, 5, 6, 8	71	First
7, 9, 11	92	Second
14, 18	162	Third
17	211	Fourth
10, 12	220	Fifth
13, 15, 16, 19, 20, 21, 22, 23, 24	Not slaked after 450 days' exposure	

Hot water slaking test

Cube no.	No. of days soaked before disintegrating	Order of slaking
1, 2, 3, 4, 5, 6, 7, 11, 12	Less than 1	First
8, 9, 10, 14, 17, 19, 20	Less than 2	Second
18, 24	5	Third
16	18	Fourth
13, 22	68	Fifth
15	72	Sixth
21, 23	Not slaked after 99 days	

Hot Water Slaking Test.—The results are given in Table IV and Fig. 17. The region high in iron is the most unstable. The region highest in Al_2O_3 and that near the middle of the three fields are next, while the most stable members are B21 and B23 whose flux molecular ratios are $.4Al_2O_3.6SiO_2$ and $.2Al_2O_3.8SiO_2$ respectively, neither contains any Fe_2O_3. These two members after undergoing the boiling test for 99 days without slaking or cracking were allowed to stand in the air at room temperature for 172 days, then placed in the hot water bath described later and broke down after soaking four days in water at a temperature of 75–85°C.

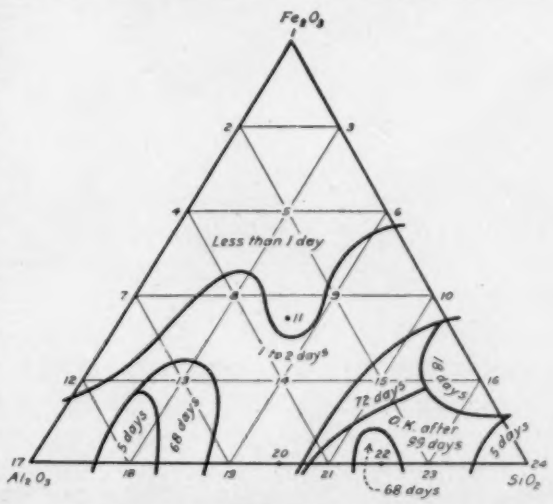

FIG. 17.—Warm water slaking test of series B.

Contrary to the air slaking test, a slight variation in the percentage composition of the fluxes appears to affect the water slaking resistance of the cubes quite noticeably, *e. g.*, 1A6 which contains 6% Fe_2O_3 and 4% SiO_2 and B10 which contains 6.4% Fe_2O_3 and 3.6% SiO_2 slaked after 18 days and 2 days respectively. 1A19 (6% Al_2O_3 and 4% SiO_2) and B20 (6.3% Al_2O_3 and 3.7% SiO_2) slaked after 5 days and 2 days respectively which tends to show that a slight variation in the ratio of Fe_2O_3 to SiO_2 has more effect on slaking properties of these mixtures than slight variations in the ratio of Al_2O_3 to SiO_2. It is also true that slight variations in the ratio of Fe_2O_3 to Al_2O_3 have a more decided effect than variations of Al_2O_3 to SiO_2. This is due to the fact as shown by the diagram, Fig. 16, that Fe_2O_3 is the least efficient of the fluxes in producing dead-burned dolomite under these conditions.

No outside air slaking test was run on Series B because of lack of material.

CERAMIC ABSTRACTS

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Art

Ceramic mosaic: standardized sheets and patterns. Associated Tile Mfgrs. (Beaver Falls, Pa.) *Arch. Forum*, **29** [5], 248–9(1923).—This mfg. catalog includes borders, all-over patterns, and diapers of various sorts, illusd. in color with sizes of the sheet units which are to be had. It represents the first fruits of standardization work carried out among ceram. mosaic mfgrs. through the assoc. F. T. H.

Cement, Lime and Plaster

The actual uses of alumina cements. Edwin C. Eckel. *Concrete*, **23**, 175–6 (1923).—Alumina cement of Amer. mfg. will be on the market in important tonnages from next spring onward. It has been manufd. and used in Europe in commercial quantity for several yrs. The alumina cements have been used in 2 different fields, each employing primarily one of its 2 exceptional qualities: (1) its resist. to chem. attack; (2) the great rapidity with which it attains max. strength. This article deals with resist. to chem. attack only, a later one to treat on quick-setting properties. A French railroad found difficulty with Port. cement in masonry work in tunnel construction in regions of alkali-water. Bied worked out these low-index alumina cements to fit this particular trouble some 15 years ago, and solved the problem. (See following abstract. Also *Ceram. Abs.*, **2** [5], 91(1923).) Three cases are cited where concrete of alumina cement resists the action of sea water better than that from Port. cement. A number of plants engaged in various branches of the chem. indus. have tried and are still trying alumina cement for tank linings, drip boards, etc. In some of these uses it has succeeded and will have a utility, in others it has failed just as badly as all of its predecessors, Port. cement included. F. T. H.

New cements and old, and what we may do with them. Editor. *Concrete*, **23**, 173–4(1923).—An article on quick-hardening cement (alumina cement) is quoted from *Concrete and Constructional Engr.* (London) in which it is concluded that it is "not without value to the user of Port. cement that the appearance of a rival cement in the market may stimulate research and possibly lead to the production of Port. cement with quick-hardening qualities." F. T. H.

High-alumina cement. J. Bied. *Revue Universelle des Mines*, July 15, 115 (1922).—Aluminous cement is essentially a cement in which the alumina content is greater or at least equal to the silica content. Ordinary Port. cement has been found to be attacked and decomposed by sea water and in tunnels and other masonry exposed to ground waters contg. calcium sulphate or magnesium sulphate, it has been found to de-

teriorate and decompose. This deterioration has been explained by the formation of the sulpho-aluminate of lime which crystallizes with 32 moles of water and the enormous increase in volume breaks down the structure. Pozzolini cement cannot be successfully used where it is warm or damp. In his researches, Vicat discovered that any cement with an index or ratio $\frac{\text{silica} + \text{alumina}}{\text{lime} + \text{magnesia}}$ greater than 1 would not be decomposed by sea water. The aluminous cements have an index exceeding 1. Tests of CaO, Al_2O_3 and $3CaO, 5Al_2O_3$, the principal aluminates present in this cement, made by P. A. BATES (Bur. Stand., Washington) show that the addn. of gypsum reduces the strength. The time of setting varied, the initial set being from 25 min. to 5 hr. and the final set from 50 min. to 7 hr. A test piece made of neat cement attained a strength of 25 kg. in 24 hr. and 56 kg. in 28 days. The mortar attained an equal strength of 24 kg. in 24 hr. but only 50 kg. in 28 days. In compression the mortar reached a strength of 250 kg. in 25 hr. and 400 kg. in 7 days, and 500 kg. in 28 days. These mono- and semi-calcium aluminates give an almost instantaneous set if mixed with as little as 1% of lime or 3% Port. cement. Bates confirmed the general fact that this cement is stronger in a mortar than pure, and stronger in a concrete than in a mortar. The set of aluminous cement commences in about 4 hr. and is complete in about 7 to 8 hr. The hardening is very rapid and in 72 hr. one can guarantee a concrete as strong as can be made using Port. cement in 90 days. Added to this is a resist. to decompn. Contrary to other cements, aluminous cement starts hardening on the interior and progresses to the outside. It has a coeff. of elasticity, almost twice that of ordinary cement. A typical analysis is as follows: Silica, 10 to 12%; Alumina, 40 to 45%; Lime, 35 to 40%; Iron oxide, 15 to 20%. The index of this is better than 1.25. Ordinary Port. cement has a silica content of 20 to 22%, alumina, 6 to 8%, and lime, 64 to 65%. Aluminous cement is produced by fusion either in an elec. or water-jacketed blast fur., or by clinkering in a rotary fur. A mixture of bauxite and limestone is used. In the blast fur., the iron oxide of the bauxite is completely reduced to steel which has a m. p. above that of the cement, and in order to tap it from the fur. a large excess of coke and a hot blast is necessary. This has lead to the introduction of heat interchangers. In the manuf. with the elec. fur. the chief difficulty is the low condy. of the alumina and limestone requiring the use of the arc fur. resulting in excessive current and electrode consumption. The rotary kiln is not so readily adaptable to the manuf. of this cement because the aluminates desired do not form readily below the fusion temp. which is much higher than that required for clinkering Port. cement. The rotary kiln would be best if refractories could be found to withstand the molten cement. There is a possibility of burning the cement mixt. in kilns such as are used for refrac. bricks. The mixt. would be made into bricks and held at a temp. just below the fusing point until vitrification took place. See preceding abstract. F. T. H.

Good mortar, mortar joints and mortar colors. ANON. *Concrete*, **23**, 97(1923).—The essentials of good mortar are: (1) It should be dense and non-absorbent. (2) It must have a sufficient compressive strength to withstand pressure in the wall without crushing. (3) It must attain strength rapidly. (4) It must be reasonable in cost and easily obtainable. (5) It must possess good working qualities. (6) It should look well. (7) It should endure permanently. Mixts. and methods for attaining these results are briefly described. F. T. H.

The Spanish cement tile industry. FRANK ANDERSON HENRY. *Concrete*, **23**, 98(1923).—Annual production of factories in Spain exceeds 300,000 sq. m. of concrete tile. Cement tiles are used for floors in place of wood. Ordinary natural colored tile are used for warehouse and factory floors and colored mosaic tiles for residence floors. The process of mfg. is described. F. T. H.

Material dealer furnishes concrete ready mixed. ANON. *Concrete*, **23**, 99(1923).—A brief description of a central mixing plant. Concrete must be used within 45 min. from time it is mixed. F. T. H.

How to make concrete roof tile. CRAWFORDSVILLE FOUNDRY CO. *Concrete*, **23**, 120–1(1923).—Specifications for mats., proportioning, machine operations and curing are described and details of equipment illusd. F. T. H.

Pittsburg, Calif. road tests. ANON. *Concrete*, **23**, 126–7(1923).—Tabulated results of tests of 13 diff. sections of concrete road giving a total computed cost including maintenance plus original cost. F. T. H.

Cost of reinforced concrete for lighter use in buildings. ANON. *Concrete*, **23**, 133–5 (1923).—A discussion of the economies of reinforced concrete skeleton construction as compared with masonry bearing wall construction. F. T. H.

Regulating setting time of Portland cement. ANON. *Can. Eng.*, **45** [20], 485–7 (1923); also **45** [21], 509–11(1923).—These articles form an abstract of Pamphlet No. 5, Brit. Port. Cement Research Assn. Experiments showed that higher temps. in the mass cause quicker setting. The setting process is more or less suspended around the f. p. of water. Increased propns. of gaging water in the mix cause somewhat slower setting. Pure, dry air has no effect upon cement samples but after about 20 weeks of exposure to the moist air of England, cement becomes practically inert, giving a loss on ignition about the same (14–15%) as set cement. Higher alumina contents and finer grinding both speed up the time of set. Various sol. salts have different effects; sea water for gaging slows up the setting somewhat. Exposure to moist CO_2 causes remarkable increases in setting speed, and also changes the character of the hardened mass. Water of crystn. is absorbed from salts by dry cement in contact with them, causing a retardation of set. Of many salts added, alkali carbonates had a marked accelerating effect on setting. Gypsum is uncertain and irregular in its effects as a retarder of setting. B. M. L.

Tests of caustic magnesia made from magnesite from several sources. P. H. BATES, ROY N. YOUNG AND PAUL RAPP. Bur. Stand., *Tech. Paper* **239** (Abstract).—The properties of oxychloride cement have been studied, particularly in reln. to the source (or properties) of the magnesite ores, conditions during the calcining process, and various oxychloride cement mixts. Ore from Greece, from 2 diff. sources in Calif., and from the State of Wash. were used, as these were representative of the chief sources of supply for this country. They include 2 diff. types of ore, the first 3 being amorphous, and the last cryst. Each ore was crushed and sepd. into 3 lots, differing only in size of particles. Size 1 contd. the particles which passed a 1-in. screen, but was retained on a $^1/_2$-in. screen; size 2 passed a $^1/_4$-in. but was retained on a No. 4 sieve; and size 3 passed a No. 4, but was retained on a No. 8 sieve. Each lot was then calcined in a 3 by 30 ft. rotary kiln under fixed conditions throughout the opern. The temp. range, including all burns, was from 700 to 1100°C. After grinding the caustic magnesia (the product from the kiln), the fineness, sp. gr., wt. per cu. ft. (loose and packed), loss on ignition, carbon dioxide content, and index of refraction were detd. There was difficulty in detg. the fineness, particularly in the use of the No. 200-sieve, on account of the finest particles of the very active magnesias adhering to the screen or agglomerating into larger particles during the opern. There were wide differences between loose and packed weights per cu. ft., which brings out the importance of weighing caustic magnesia, when making up mixts., rather than measg. by vol. as some do. Although a min. and max. carbon dioxide content has often been used in specifs. for caustic magnesia, no reln. was found between this constituent and the behavior of the oxychloride product. The index of refraction gives promise of being valuable in detg. degree and uniformity of burning, but will not indicate changes in the mat., occurring during storage, that have a marked

effect on the properties of the cement. It was necessary to "age" some of the very active magnesias to make them usable. Caustic magnesia from each lot was used in mixes prepd. according to 3 flooring, 2 stucco, and one lab. test formula. Only one concn. (22 Bé.) magnesium chloride soln. was used for mixing with the dry mat., as this concn. is conceded to be the best for general use. Service tests were made in conjunction with the lab. tests. The consistency of the wet mixt. (excepting the lab. test mix) was such as is generally used in practice, and was kept the same in all cases, as nearly as possible. The service tests consisted of the laying of flooring panels; erection of stucco panels, all exposed to actual service conditions; and subsequent observations, including meas. of linear changes. Three types of specimens were used in making strength tests. The briquette (of the shape used in the standard strength test for Port. cement mortar), for tensile strength; a $^1/_2$ by 2 by 13-in. bar for transverse strength; and a 2 by 4-in. cylinder, for compressive strength. In order to get an indication of the effect of intermittent wetting and drying of the set stucco during its early life, such as the material generally receives from exposure to the weather, specimens were tested in the following manner. After storing 21 days in the laboratory air, they were placed in water for one day, followed by one day in air under certain temp. and humidity conditions. This cycle of water and air storage was repeated twice, and after an additional day in air (making 28 days in all), the strength tests were made. Also, linear changes, resulting from this treatment, were detd. The lab. specimens for expansion tests were $^1/_2$ by 2 by 13-in. bars. The meas. were made by means of a 10-in. Berry gage. The results show that the various ores used require different conditions of calcination in order to produce caustic magnesias of approx. the same quality. Very light burning produces a magnesia which is too active for use in the customary oxychloride cement mixts. without "aging" or the use of a retarder. An increase in the degree of calcination increases the time of set of the magnesia. Also, the deg. of calcination affects, to a great extent, the strength, water resistance, and vol. change of the set cement mixt. However, there are other factors which influence these properties nearly as much if not more (within reasonable limits) than the burning. By the use of different types of aggregates with a magnesia, products very different in behavior under test, may be obtained. Also, by changing the proportion of given aggregates, the products may be made to differ widely. Therefore, a magnesia considered good in quality may be made to give very unsatisfactory results, and one considered very poor often may be made to give excellent results. (The complete paper may be purchased from the Supt. of Documents, Government Printing Office, Washington, D. C., price 10c.) H. F. S.

Proper handling of lump lime. ANON. *Contract Rec. and Eng. Rev.*, **37**, 1071, (1923).—When using a quick-slaking lime, if insufficient water is added, the paste is not as plastic and works short. It feels slightly gritty, and has a yellowish tinge. The temp. of the mass is raised considerably above boiling point, and a new chem. reaction takes place. This results in a formation of a subs. which absorbs carbon dioxide at a rapid rate, and thus hardens before it may be used. Exactly what this new compound is, has not been definitely detd., but the result is well known by those who use lime. In the case of "drowned" lime, the excess of water has absorbed too rapidly the ht. for slaking, and the change from quicklime to paste is retarded. When the paste is formed it is thin and watery and unsatisfactory. A good lime putty, properly prepd. and allowed to age or soak for some time previous to its use, makes a mortar or plaster that is easily applied; aging the paste imparts to it a degree of smoothness not otherwise obtained. O. P. R. O.

Effect of organic decomposition products from high vegetable content soils upon concrete drain tile. G. R. B. ELLIOTT. *J. Agr. Research*, **24**, 471–500(1923).—Concrete

tile as at present made breaks down in all peat soils or when exposed to the action of peat waters. The more porous the tile the more rapidly it disintegrates, and an acid soil aids in the disintegration. A high percentage of lime in the soil delays but does not stop the decompn. of the tile. Methods are described for increasing the permanency of concrete tile in peat soils. W. H. R. (*C. A.*)

BOOK

Nineteen Stories of Lime. TRADE PUBLICATIONS. The title of a new book issued by the Central Division of the National Lime Association illustrating the various uses of hydrated lime in concrete construction. The various advantages which are attributed to the use of hydrated lime in concrete are: watertightness, workability and resilience. F. T. H.

Enamels

PATENT

Method of marking enameled ware. EMIL S. DENK. U. S. 1,473,903, Nov. 13.

The method of marking enamel ware, comprising coating the enameled surface over the area to receive the mark with tacky material, applying to the coating an enamel, again coating the coated surface partially or wholly with a tacky material, applying to the part so recoated an enamel, and treating the ware to render the composite mark permanent.

Glass

On the refractive index changes in optical glass occasioned by chilling and tempering. F. TWYMAN AND F. SIMEON. *Jour. Soc. Glass Tech.*, **7** [27], 199(1923).—The changes in refractive index due to the tempering and chilling of a dense barium crown glass and a borosilicate crown were detd. The data is given and the results are plotted. *Conclusions:* (1) It has been established that the effect of chilling the dense barium crown glass and borosilicate crown samples referred to may be the lowering of the refractive index by as much as 0.004 in the case of the former, and 0.0013 in the case of the latter. (2) This lowering of refractive index is removable by htg. to a temp. for a length of time which have been ascertained for certain cases; (3) If the dense barium crown glass be cooled from the annealing temp. slowly under pressure, and measured not under pressure, the resulting refractive index is higher than when it is similarly cooled free from pressure, by amts. of the order of 0.00035; (4) The effect under (3) above seems to us to require further investigation for its complete elucidation, but for practical purposes the main effect of the chilling alone appears of importance; (5) It is clear that a want of homogeneity could be produced by molding, owing to surface chilling, which requires for its removal a longer maintenance at the high temp. than will suffice to remove elastic stress from the homogeneous sample. J. G. P.

A note on the suitability of quartzose residues for glass manufacture. D. J. REES. *Jour. Soc. Glass Tech.*, **7** [26], 130(1923).—The residues from the crushing plants in the Kolar Goldfield, Mysore, India, were examd. for the purpose of detg. their suitability for making glassware. This investigation indicated that residues such as those from the Kolar Goldfield would be a satisfactory raw mat. for use in the manuf. of common glassware when freedom from color is unessential. J. G. P.

The year in review in the world of glass technology. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **7** [26,] 132(1923). J. G. P.

The physical properties of boric oxide containing glasses and their bearing on the general problem of the constitution of glass. S. ENGLISH AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **7** [26], 155(1923); see *Ceram. Abs.*, **2** [12], 275(1923).—Measurements were made of the thermal expansion, the refractive index and dispersion of two series

of sodium borosilicates, the first series contg. approx. 20% of sodium oxide, the second 10%. In each case the silica present was progressively substituted by boric oxide until in the 20% Na_2O series as much as 43.7% B_2O_3 was present, and in the 2nd series 46.07%. Results show that the linear relationships between chem. compn. and phys. properties, which had been found to subsist over a considerable range for many types of glasses, do not hold in the case of the sodium borosilicate glasses. Minima occur in the thermal expansion curves, and max. in the case of the density and refractive index, as also in the case of the annealing temp. The detd. results on thermal expansion show that Winkelmann and Schott's thermal expansion factors clearly do not hold for the boric oxide glasses, except over a very limited range. On practical grounds, the value of boric oxide for the prepn. of glasses of low thermal expansion is shown to be limited, since beyond a certain amt. the expansion increases instead of decreases. Various theories are discussed to explain the special results obtained in the case of the boric oxide glasses. J. G. P.

Stainless steels from the point of view of the glass industry. W. H. HATFIELD. *Jour. Soc. Glass Tech.*, **7** [26], 142(1923).—The properties of the various types of stainless steels were examd. The strength of stainless steel, as detd. on the tensile testing mach., varies according to the compn. and to the deg. to which the temp. is drawn, from above 100 T. per sq. in. breaking load in the hard condition, down to 30 to 40 T. per sq. in. when fully tempered. A specimen series of figures, obtained with a steel contg. 0.30% of carbon, is given. The mechanical properties of stainless steel in the hardened and slightly tempered condition were detd., and lab. tests in full details are given. Fatigue tests were also carried out on stainless steel in the hardened and slightly tempered condition, and results are given. Tests on stainless steel at high temps. show that it maintains its strength to a much greater degree than ordinary structural steel and may, therefore, be employed with advantage where parts have to withstand stress at temps. above normal. Tests on hardness as affected by increasing temps. were made and the results indicate that the energy absorbed is not substantially modified until temps. approaching 600° are attained. Tests performed up to 1000° on mild steel, alloy steels, tungsten steels, and stainless steels showed that the stainless steel scaled less than any of the others. The microstructure of stainless steel is described and its general phys. properties are given. J. G. P.

A rapid method of testing the durability of glassware. H. S. BLACKMORE, VIOLET DIMBLEBY AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **7** [26,] 22(1923).—An investigation is conducted on the suitability of a soln. of narcotine hydrochloride for testing the durability of glassware. A description of the test is given. *Conclusion:* The narcotine hydrochloride test applied under the conditions outlined in the paper is quite a satisfactory method of testing rapidly the durability of glass towards water. J. G. P.

A study of the melting and working properties of boric oxide glasses, with special reference to the borosilicates. VIOLET DIMBLEBY, F. W. HODKIN, M. PARKIN AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **7** [26], 80(1923).—A discussion. J. G. P.

Tank furnace works organization. T. C. MOORSHEAD. *Jour. Soc. Glass Tech.*, **7** [26], 105(1923). J. G. P.

Organizing for production from pot furnaces. W. W. WARREN. *Jour. Soc. Glass Tech.*, **7** [26], 83(1923). J. G. P.

Investigation of pot-attack. W. ROSENHAIN. *Natl. Phys. Lab.* (Rept. for 1920, 124 pp.).—Further study of pot-attack shows that convection currents caused by temp. differences between top and bottom of pot are a factor which may disguise the convection currents set up by changes in density. It is suggested that maintaining the top of the pot at a higher temp. than the bottom will minimize the attack. E. S.

Determination of the viscosity of glass. W. ROSENHAIN. *Natl. Phys. Lab.* (Rept. for 1921, 186 pp.).—The viscosity of glass at temps. from 400°C to 700°C has been detd. by measg. the rate of twist under a known torque of rods of the glass in question. E. S.

Some phenomena of pot-attack. W. ROSENHAIN. (Collected Researches.) *Natl. Phys. Lab.*, **15,** 112–32(1920); *Trans. Soc. Glass Tech.*, **3** (1919).—The depth of attack by molten glass on the walls of a pot or on a clay rod inserted in the glass, increases in linear reln. with the distance below the surface of the glass. This is shown to be due to circulating currents set up by the decrease in density of the glass caused by soln. of the clay at the surface of contact resulting in unsatd. glass striking the bottom of the pots. The same phenomenon, occurring locally in small pits results in the "drilling" of pots. In the case of soln. by water these phenomena are generally reversed because the solutions are denser than the solvent, but with org. solvents they can be duplicated exactly. In the case of glass it is possible to control the currents and shift the zone of "drilling" by the use of a protecting ring of inert material, *e. g.*, zirconia. The rate of attack increases with the temp. The use of the X-ray is advocated for the detection of iron specks, air cavities, etc. E. S.

The casting of pots for experimental work on optical glass. ALICE B. TAYLOR. (Collected Researches.) *Natl. Phys. Lab.*, **16,** 289–98(1921); *Trans. Soc. Glass Tech.*, **4** (1920).—In casting pots, if the slip is too thin, the grog separates, while, if it is too thick, bubbles are trapped. These difficulties are overcome by rapidly filling the mold with slip under an air pressure of 20 lbs. per sq. in. Good results are obtained only in a narrow range of viscosity. E. S.

Chemical resistance of glass for the laboratory. A. MAURI. *Giorn. Chim. ed Appl.*, **5** [10], 495(1923).—Jena, Murano and Pyrex glass were investigated by treating with H_2O for a week, boiling H_2O for 3 hr., in H_2O at 134°C for 3 hr., 2 *N* H_2SO_4, boiling 2 *N* HCl, 2 *N* NaCl, 2 *N* NH_4Cl, *N*/10 NaOH, *N*/10 Na_2CO, 2 *N* NH_4OH, *N*/1 Na_2S. The Na_2S affected the glass the most. Jena and Pyrex lost nearly same wt. while Murano was less affected in all cases. H_2O, H_2O boiling 3 hr., 2 *N* NH_4Cl, and 2 *N* NaCl had no effect on the samples. S. S. C.

Measurements on the gases evolved from glasses of known chemical composition. J. E. HARRIS AND E. E. SCHUMACHER. *Bell System Tech. Jour.*, **2,** 122–32(1923).—Six kinds of glass were used, representing soda-lime, soda-potash-lead (lamp glass), and borosilicates of lead and soda. The specimen was placed in a container made of the same glass, and heated as close to the softening range as it was possible to go without causing the container to collapse. The gases driven off were examd. and classified as follows: (*a*) gases condensable above −78°C, (*b*) condensable between −78°C and 190°C (*c*), not condensable at 190°C, these fractions representing (*a*) water vapor, (*b*) carbon dioxide, (*c*) permanent gases: oxygen, nitrogen, hydrogen. The H_2O vapor was removed by surrounding the condensation trap with a mixt. of frozen and liquid acetone, and the CO_2 with liquid air. A McLeod gage was used to meas. the pressure of the evolved gases, and from the pressure the vol. was computed. It was found that at 200°C, the evolution of gas reached a max. for most specimens, thus proving that the adsorbed gas is driven off at that point. For the borosilicates, this point was 300°. Near the softening point (400°C for most specimens, 600° for Pyrex), the evolution of gas increased, this representing absorbed as well as adsorbed gas. The data shows a parallelism between per cent $Na_2O + K_2O$ and vol. of adsorbed CO_2, which would indicate that adsorbed CO_2 is held by primary valence forces. It would seem that CO_2 is taken up by a film of NaOH formed by slow hydrolysis of the glass. In general, glasses running high in alkali give off more water vapor as well as CO_2 than do those of lower alkali content. By subjecting glass to a heat treatment of between 1500° and

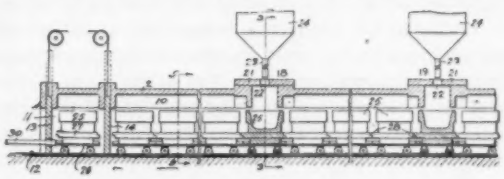
1600°C for one hour, the absorbed gases were practically eliminated, as shown by the small amt. of permanent gases obtained on the test, whereas H_2O and CO_2 remained as adsorbed gases. The conclusion is drawn that glass relatively free from absorbed gas can be produced by htg. the glass during the melting process to a sufficiently high temp. The greater viscosity of the borosilicates makes it more difficult to render them gas-free. A. F. G.

Silica glass or fused quartz. ELIHU THOMSON. *Gen. Elec. Rev.*, **26**, 68–74(1923).—. Historical account of manuf. of fused silica, with special ref. to author's patented elec. fur. process. Of particular interest are the illust. which include photographs of telescope reflector disks of clear quartz 1 ft. in diam., and large strain insulators of opaque quartz 10″ in diam. Stress is laid on the peculiar advantages offered by fused silica, due to its extremely low expansion: It is possible to figure an optical surface of quartz without affecting the curvature by the heat of polishing; a reflecting telescope with quartz mirror would show no distortion under irregular htg., which is a serious defect of glass reflectors; quartz can be shaped by grinding whereas glass would be cracked by the ht. developed. Due to its high m. p., metals can be cast into recesses or holes in the quartz, without shattering the latter. A. F. G.

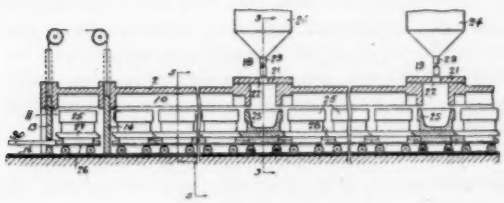
The manufacture of glass marbles. C. J. STAHL. *Glashütte*, **53**, 356–7, 371–2, 403–4, 419–21, 435–6(1923). J. B. P. (*C. A.*)

PATENTS

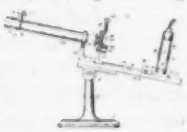
Method of melting glass in pots. FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,476,431, Dec. 4. The method of melting glass in pots consisting in introducing the pots into a htg. chamber, moving the pots through said chamber, maintaining the temp. in said chamber as the pots move through same whereby the glass is melted and fined, and admitting batch to said pots at intervals in their passage through said heating chamber, the said pots being introduced into said htg. chamber and removed therefrom without exposing said chamber to the outer air.



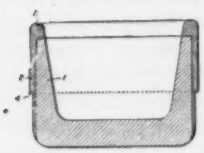
Glass-melting-pot furnace. FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,476,432, Dec. 4. A continuous pot-fur. for melting glass having a plurality of moving carriers therein, means for charging batch into said pots at intervals in said fur., means for varying the temp. at different portions of said fur., and means for introducing the pots into said fur. and removing the pots therefrom without opening the htg. chamber of said fur. to the outer air.



Lens-testing instrument. WALTER C. SCHLITZER. U. S. 1,475,515, Nov. 27. A lens testing instrument comprising means for supporting a test lens, a lamp housing located on one side of said lens supporting means and having an opening at one side thereof, a sleeve adjustable on the housing and positionable over said opening, the sleeve having a light emitting opening that is adjustable to proper relationship with the test lens and acts to project rays of light onto the test lens, a sight

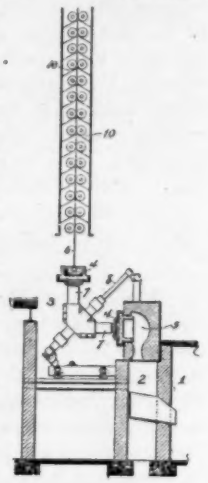


tube on the opposite side of the lens supporting means, an image screen within the tube, and a condensing lens between the image screen and lens supporting means.



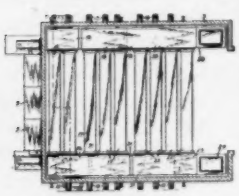
Glass-melting pot. FRANK OSBORNE. U. S. 1,475,650, Nov. 27. An open top plate glass melting pot provided with an annular shoulder and having a body portion of pot clay, and a rim and an outer shell for the body portion of a clay which is more refrac. than that of the body portion, such shell extending down from the rim to a point below the shoulder of the pot.

Art of drawing glass. HUGO J. WALTER. U. S. 1,475,527, Nov. 27. The improvement in the art of drawing glass sheets which consists in presenting charges of molten glass successively to a drawing app., drawing a sheet from each charge of glass, and causing each sheet drawn to serve as a bait for the succeeding sheet whereby the successive sheets will be welded together.



Arsenate of lime product and process of making same. LOUIS CHARLES DREFAHL. U. S. 1,475,545, Nov. 27. Process of making a stable, water-insol. arsenate of lime product which comprises pptg. calcium arsenate in a medium maintained at a temp. of from 120°F to 160°F.

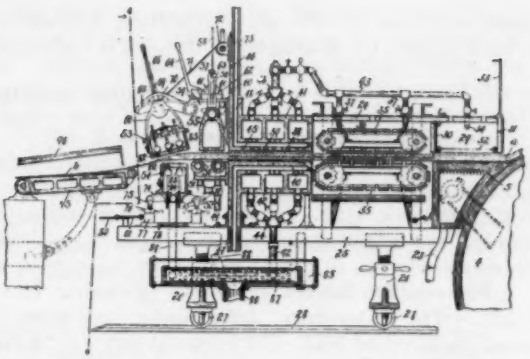
Lens and blank therefor and method of marking it for the purpose of identification. THEODORE B. DRESCHER. U. S. 1,475,473, Nov. 27. A transparent refracting lens of glass having a portion of the mat. of which it is composed slightly modified or altered in the form of a designating mark less in area than the surfaces thereof, said marking or tinting extending through the lens from one surface to the other. The herein described method of marking glass lenses and blanks therefor for identification purposes consisting in slightly altering or modifying the glass of which they are composed from one surface to the other in definite designs by subjecting limited portions thereof corresponding to the design desired, to the rays projected from an electrically excited vacuum tube, the duration of the exposure being only sufficient to render the design perceptible but without appreciably affecting the light transmitting or refracting powers of the lens or blank.



Leer. GEORGE W. BATCHELL. U. S. 1,473,897, Nov. 13. In a leer, a plurality of flues, a gas inlet for permitting gas to enter the flues, the flues interconnected to form a continuous passageway for the gas through the leer, a burner located at one end of the connected flues, air inlets located at the ends of the flues to draw the air into the flues in the direction that the flame from the burner is moving to maintain the flame and the combustion of the gas as it progresses through the flues. In a leer, a plurality of flues, a gas inlet for permitting gas to enter the flues, the flues divided into sets of parallel connected flues, the sets of flues interconnected to form a continuous passageway for the gas through the leer, the number in each set increasing progressively towards the stack end of the leer.

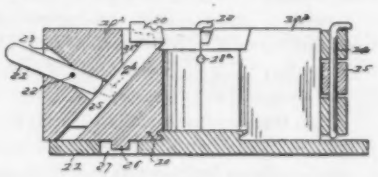
Method and apparatus for forming glass. ROBERT M. CORL. U. S. 1,474,019, Nov. 13. The method of forming glass, which consists in flowing a continuous column from a source of molten glass, progressively cooling the column below the point where gravity will vary its cross-section, progressively melting the advance end of the cooled column in such a manner that the melted portion will flow over the cooled portion and

vary the cross-section of the column and allowing the glass to set in the cross-section resulting from such flowing. See *Ceram. Abs.*, **2** [11], 249 (1923).

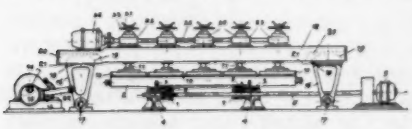


Leer for annealing glassware. DAVID STENHOUSE. U. S. 1,474,058, Nov. 13. A leer for glassware, comprising a horizontally disposed main annealing chamber of substantial length, said chamber having ascending and descending legs communicating with its opp. ends and being located at a relatively great elevation whereby is created a natural seal for confining ht. thereto, the ascending leg having a charging opening therein adjacent to its lower end, and an approx. horizontal cooling chamber communicating with said descending leg, and an endless ware conveyor arranged for advance travel from the charging opening to and through said cooling chamber and for return travel throughout a path in which its temp. is raised to the required point by absorption of ht. given off by the ware and the leer walls.

Glass mold. JOHN G. MORITZ. U. S. 1,474,329, Nov. 13. A molding app. of the type indicated having a section or mold body and a ring or cap provided in their contact faces with complemental registering channels combining to form a handle mold in communication with the interior of the receptacle mold, and means for upwardly deflecting the molded handle after the completion of the molding operation and consisting of a lifter block movable with relation to and carried by one of the mold sections.



Apparatus for grinding, smoothing, and polishing glass, plate glass, and other material substances. CHARLES HEUZE. U. S. 1,474,672, Nov. 20. App. of the character described, comprising a table for supporting the work; a succession of rows of tools extending above and across the table, each row having an individual support; mechanism for imparting an endwise reciprocating bodily movement to all of said supports simultaneously, but moving the odd-numbered supports in one direction and the even-numbered supports in the opposite direction; and mechanism for rotating all of the tools of a row simultaneously. Apparatus of the character described, comprising a table for supporting the work; a succession of rows of tools extending above and across the table, each row having an individual support; mechanism for imparting an endwise reciprocating bodily movement to all of said supports simultaneously, but moving the odd-numbered supports in one direction and the even-



numbered supports in the opposite direction; and mechanism carried by and individual to each support for rotating all of the tools in the corresponding row simultaneously.

Heavy Clay Products

House insulation and fuel consumption. H. J. BURT. *Concrete*, **23**, 117–18(1923).—Insulating lumber is supplied in sheets and replaces lath. The unit B.t.u. ht. loss for 1 in. thickness is given: insulating lumber, 0.33; wood sheathing, 1.25; plaster, 1.50; brickwork, 4.00; concrete, 6.00. By the addn. of insulating lumber to ordinary forms of wall construction there is a ht. saving of from 30 to 40%, which the author claims should result in at least 25% fuel saving in residence construction. F. T. H.

Fire-resistive houses a reality. WHARTON CLAY. *Arch. Forum*, **39** [4], 33 (1923).—The Underwriters' Laboratories have announced that a wood-studded partition plastered on both sides by metal lath and plaster, and an ordinary wood-stud floor as commonly constructed, but protected on the under side with metal lath and plaster, will resist the intense ht. of their standard fire test for over one hr. and remain intact and carry its load beyond that period. They claim that ordinary lath and plaster will expose the wood behind, under the same conditions, in about 4 min. F. T. H.

Study effect of moisture on concrete slabs. ANON. *Cement & Eng. News.*, **35** [9], 30(1923).—Progress report of tests being conducted by U. S. Bureau of Public Roads, in conjunction with Eng. Exp. Sts. of Purdue Univ. Moisture, like heat, sets up internal stresses which probably tend to aid failure of concrete roads. Freezing of this moisture produces still greater stresses. 75 slabs are being tested in a specially constructed testing machine, in which alternate transverse failure occurs in less than two minutes. F. T. H.

Standard sizes for cement block and brick. ANON. *Concrete*, **23**, 162(1923).—Concrete brick to be the same as adopted for clay face brick: rough $2^1/_4$ x $3^3/_4$ x 8 in.; smooth, $2^1/_4$ x $3^7/_8$ x 8 in. Tentative standard sizes for concrete block and tile: Foundation concrete units: height $7^5/_8$ in., length $15^5/_8$ in. Wall thicknesses, 8 and 12 in. (thickness of units); load bearing wall concrete units, height $7^5/_8$ in., length $15^5/_8$ in. Wall thicknesses, 6, 8, 10 and 12 in.; load bearing wall concrete structural tile, height 5 in., length $11^5/_8$ in.; wall thicknesses, 4, 8 and 12 in.; concrete partition tile, height $7^5/_8$ in., length $15^5/_8$, 18 and 24 in.; wall thicknesses, 3, 4, 6 and 8 in. F. T. H.

Fire tests of brick walls. S. H. INGBERG. *Amer. Arch.*, **124**, 307–18 and 355–62 (1923).—*Scope of tests.* A rept. of a part of a program of tests to det. the effectiveness of brick walls as fire barriers and to obtain definite knowledge of their ht. insulation and stability under fire conditions. The series includes fire endurance tests and fire and water tests with 2 types of surface clay brick, 1 shale, 2 sand lime brick and 1 Port. cement brick. Auxiliary compressive, transverse and absorption tests were also made. (1) *Test specimens and construction details.* The test walls built on contract based on competitive bids to obtain representative workmanship were 11 ft. high and 16 ft. wide, being contd. in movable frames placed for test to form one side of the test fur. Some panels were restrained and some were unrestrained to represent varying conditions of use. Further tests of walls under load are to be made. (2) *Testing methods.* The fire exposure is obtained with oil burners and is regulated to conform to a predetd. time-temp. reln., 1700°F in 1 hr., 1850°F in 2 hrs., and 2150°F in 6 hrs. Temperatures in the fur., in the wall and on the unexposed side of the wall are measured by the thermo-elec. method. Six hrs. was the limit for the endurance test. In the fire and water test the wall was exposed to the fire for 1 hr. and then to a hose stream from a $1^1/_8$ in. nozzle under 50 lb. per sq. in. water press. was applied. (3) *Test charac. and results.* (*a*) *Deformation and cracking.* The first visible ht. effects were deflections toward the fire. Cracking along mortar joints and through brick were next noted. In

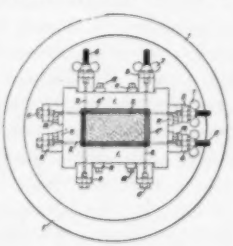
point of freedom from cracking the bricks in the series can be roughly placed in the following order: Eastern surface clay, Western surface clay, concrete, sand-lime and shale. (*b*) *Heat effects.* The first indication was issuing of steam from free water from open or imperfect mortar joints. The time required to reach on the unexposed side a temp. of 150°C (302°F), the danger point for hazardous occupancies varied from 1 hr. 25 min. with 4-in. walls to over 6 hr. with some 8-in. and all 12-in. walls; 250°C (482°F), the danger point for non-hazardous occupancies was reached in less than 6 hrs. by the hollow 8-in. walls and by the 4-in walls. The final temp. at 6 hr. varied from 83°C with the 12-in. walls to 252°C with the 8-in. hollow walls. (4) *Conclusions.* From a study of the condition of the tested walls, the deflections and the temp. reached Ingberg gives the fire resistance periods of brick walls as follows:—

Thickness	Type	Interior structural members framing into wall	Materials protected	Load on wall	Fire resistance period
4-inch	Solid	Incombustible and fire resistive	Non-hazardous	Non-bearing	1 hour
8-inch	Solid	Incombustible	Non-hazardous	Non-bearing	4 hours
8-inch	Solid	Incombustible	Hazardous	Bearing or non-bearing	2½ hours
8-inch	Solid	Combustible	Hazardous or non-hazardous	Bearing or non-bearing	1½ hours
8-inch	Hollow	Incombustible and fire resistive	Non-hazardous	Bearing or non-bearing	2½ hours
8-inch	Hollow	Incombustible and fire resistive	Hazardous	Bearing or non-bearing	1½ hours
8-inch	Hollow	Combustible, on one side only	Hazardous or non-hazardous	Bearing or non-bearing	¾ hour
8-inch	Hollow, filled solid at floor lines	Combustible or incombustible	Hazardous or non-hazardous	Bearing or non-bearing	1½ hours
12- or 13-inch	Solid	Combustible or incombustible	Hazardous or non-hazardous	Bearing or non-bearing	4 hours
12- or 13-inch	Hollow	Incombustible and fire resistive	Hazardous or non-hazardous	Bearing or non-bearing	4 hours
12- or 13-inch	Hollow	Combustible	Hazardous or non-hazardous	Bearing or non-bearing	2 hours
12- or 13-inch	Hollow, filled solid at floor lines	Combustible or incombustible	Hazardous or non-hazardous	Bearing or non-bearing	4 hours

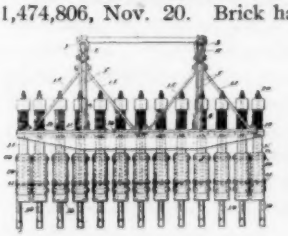
H. D. F.

PATENTS

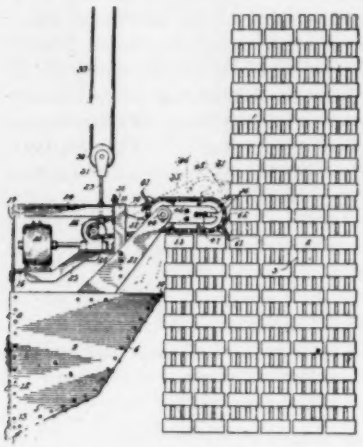
Manufacture of bricks. FREDERIC P. JONES. U. S. 1,475,832, Nov. 27. The manuf. or production of bricks or blocks of the kind referred to, characterized by sepg. an unbroken slice of the full surface dimensions from the formed body and then reuniting the severed slice to the body by a pressing means capable of simultaneously ornamenting the surface of the slice.



Brick-handling fork. WILLIAM W. WALLACE. U. S. 1,474,806, Nov. 20. Brick handling app. of the kind described, comprising an overhead support, a plurality of horizontally extending brick engaging fingers and means connecting said fingers and said support consisting in a vertical bearing rigidly attached to said frame, a carriage adapted for vertical sliding movement on the bearing member and carrying the horizontal fingers, anti-friction



members between said carriage and said bearing and positive stop means coöperating with said anti-friction members to limit the vertical movement of said carriage.



Apparatus for removing burnt brick from a kiln, stack, pile, or the like. ALEXANDER A. SCOTT. U. S. 1,474,793, Nov. 20. Apparatus of the kind described, comprising a brick-carrying receptacle, means coöperating with said receptacle to extend therefrom, and engage the rows of brick remote from said receptacle, said engaging means constituting brick removing means to transfer brick from a stack to the receptacle, and including an endless conveyor, having brick moving devices thereon, said endless conveyor being arranged for variable vertical positions with regard to the brick.

Refractories

Bauxite and aluminum in 1922. JAMES K. HILL. *U. S. Geol. Surv.* (Mineral Resources of the U. S.), [1], 87–96(1922).—The domestic production of bauxite increased 122% in 1922 over 1921. The amt. produced was not as great as in 1920. The increase in the eastern fields showed a revival of the aluminum salts indus. The main producing states for bauxite in 1922 were Ark. and Ga. In the last few yrs. high alumina clays have been substituted for bauxite in mfg. refrac. The main source of these clays is Mo. Three grades of clay contg. 55%, 65% and 75% Al_2O_3 are regularly handled. The U. S. produces more bauxite than the rest of the world. The diaspore deposits of Mo. are being rapidly developed. 40,000 tons of diaspore clay were sold to consumers. Diaspore in cryst. form is of commercial interest. Diaspore can probably be used for the manuf. of abrasives and aluminum salts. Kyanite, sillimanite and andalusite, aluminum silicates containing more than 60% Al_2O_3, can probably be substituted in some cases for diaspore and bauxite. Large deposits of kyanite have been discovered in Wyo. and Ariz. Alunite is being mined and treated in Utah for potash. Some of the by-product Al_2O_3 is being used for the manuf. of refrac. Some data are also given on the production and consumption of bauxite for the various industries. T. N. McV.

Lining acid electric furnaces. J. M. QUINN. *Iron Age*, **111** [16], 1101–2(1923).—Careful selection of mat. for lining an acid elec. fur. is essential. Two grades of ganister are available, crushed and ground. The former is $^1/_2$ in. mesh with 50% smaller than $^3/_8$ in. The latter is $^1/_4$ in. mesh with a large propn. of fines. Crushed ganister is the more refrac. of the two. Silica sand may also be used. Glutin, molasses and water glass are used as binders with these mat. Silica brick are very satisfactory for linings. The best method for lining an acid fur. is to use high grade silica brick for the bottom and side walls. The brick should be laid dry, leaving room for expansion. The fur. should be heated up gradually until the brick just begin to melt. The bottom should be burned in layer by layer with moistured silica sand. The cup shaped bottom is preferred to the saucer shaped. A fur. can be lined at less expense by using rammed-in ganister instead of silica brick. Directions are given for ramming in the ganister lining and burning it in. Silica brick are usually used in the roof. The author advises against the use of insulation. M. E. M.

Acid electric steel furnace operation. J. M. QUINN. *Iron Age*, **111** [17], 1177–9(1923).—The scrap charged should be slightly below the max. limits for sulphur and

phosphorus, and not too high in carbon. Charge all the scrap at one time, placing large pieces and those highest in carbon on the bottom. With very rusty scrap, free from sand, some silica sand should be shoveled in to prevent the charge attacking the lining. It is possible by careful melting and selection of scrap, to have completely deoxidized metal in 10–15 min. If trouble occurs, and the first test shows carbon over 1%, it is well to pig the heat. If it is decided to work the heat, ore or scale is added carefully, to decarburize the metal. The black oxidizing slag remaining should be removed from the fur. if of large vol., and a new slag made of clean silica sand. While the slag is black both it and the metal contain oxides, which must be reduced. This is done by throwing fine coal or coke on it. Some SiO_2 is reduced under the arc, the nascent Si produced helping to deoxidize the steel. Other reducing agents sometimes used are ferrosilicon, ferromanganese, aluminum, and lime. When the metal is completely degasified, the alloy additions made, and the correct temp. reached, it should be poured from the furnace quickly, as any delay will make a thick, unwieldy slag. M. E. M.

Effect of carbon monoxide on refrac. ANON. *Metal Industry* (London), **23,** 472(1923).—Large scale expts. with electro-thermic dry distillation process for treatment of zinc ores recently undertaken by Mississippi Valley Expt. Station of the U. S. Bureau of Mines have been hampered by rapid disintegration of condenser linings of ordinary fire brick. This disintegration was due to the action of carbon monoxide which caused increase in volume of the brick by deposition of carbon around iron oxide particles in the refrac. mat. Disintegration was avoided by the use of iron-free refrac. mat. R. J. A.

Dolomite for refractories. ANON. *Metal Industry* (London), **23,** 460(1923).—Research work on the utilization of dolomite in refracs. is being continued by U. S. Bureau of Mines at Columbus, Ohio. The main problem being studied is to combine the lime in dolomite so it will be non-slaking and at the same time hold up the refracs., thereby rendering available abundant deposit of dolomite for use as a basic refrac. Previous work has indicated that one of the best fluxes is alumina-iron flux. More recent work has consisted in slaking lime tests on varying proportions of dolomite and alumina-iron flux; 5 to 50% of flux was used and the refrac. properties as well as slaking tendencies were studied. After the best propn. was detd. bricks were made and the proper firing procedure then studied. As a result, a compn. has been found which, when compounded with proper binder and properly burned, produces a strong non-slaking brick of high refractoriness. The bricks are satisfactory except that uniform shrinkage has not been completely attained. R. J. A.

Refractories for the aluminium industry. R. J. ANDERSON. *Metal Industry* (London), **23,** 441–2(1923).—(Abstr. of paper before Refrac. Division, AMER. CERAM. SOC.) A. discusses refracs. for melting substantially pure aluminium and aluminium alloys, both from the point of view of the setting for furs. and use as the containing vessel or hearth. While req. melting temps. are low, the corrosive action of liquid aluminium is great, causing failure of refracs. Carbon is used for lining furs. for the electrolytic reduction of primary aluminium. This is remelted for pigs or ingots in reverberatory type furs. Reverberatory fur. with high-grade fire brick lining are usually employed in rolling-mill practice for melting substantially pure aluminium. Alloys are usually melted in iron-pot or crucible furs. unless production is large, when reverberatory fur. are used. The various types of furs. used in light-alloy foundry practice are discussed. The iron-pot fur. is most favored; in this, the shell is lined with fire brick and the alloy melted in a cast-iron vessel, usually made of ordinary gray foundry iron, but sometimes of a mixt. of 40% semi-steel and 60% foundry iron. The av. life is about 40 heats. Further research is needed on question of refracs. and contg. vessels for melting in die casting and permanent-mold casting practice. Present iron-pot methods are not satis-

factory owing to dissolution of iron. Alundum linings are not successful. The linings for furs. in secondary smelting of aluminium and aluminium alloys is an important factor. The life of fur. linings in secondary work is low owing to local burning. Reverberatory, crucible and iron pots are used, and requirements are severe owing to the high temp. generated by the oxidation of aluminium and the use of fluxes which are destructive to linings. R. J. A.

The commoner refractories. C. E. MOORE. *Metal Industry* (London), **23,** 458 (1923).—(Abstr. of paper before Birmingham Met. Soc.) M. calls attention to the dangers arising from vol. changes in fire bricks at different temps., involving buckling of arches in furs. The conversion of quartz in silica brick is much more slow than in ganister, but silica brick requires very careful treatment during htg. and cooling; it does not usually deform until 1500° is reached. An increasing amt. of semi-silica bricks contg. 80% silica is being used, which are very suitable for some purposes; these are being employed to an increasing extent in the U. S. for coke ovens. An efficient refrac. must resist slag action and compression at alternation of temp., and must also stand up well to cutting flames and gas impact. It is important to use the highest temp. possible in manuf. of bricks so that failure in use at high temps. may be prevented. In the U. S. where the use of oxygen is desired for fur. work, the greatest difficulty is to find refrac. to withstand much higher temps. which the employment of oxygen involves. R. J. A.

The care of brass foundry crucibles. C. F. HOPKINS. *Metal Industry* (London), **23,** 459–60(1923).—(Abstr. of paper before Phila. Foundrymen's Assoc.) H. discusses the storage, drying, and annealing of brass-foundry crucibles, and their treatment in the fur. Instances are cited where proper annealing markedly increased the life of crucibles. It is pointed out that handling of crucibles, in many foundries, before being used, is bad. The effect of furnace design upon crucible life is discussed. Methods of handling crucibles are taken up, and sketches illus. correct and incorrect methods of handling with tongs. Crucible life is greatly affected by rough and improper handling R. J. A.

Preparation of super-refractories. ANON. *Metal Industry* (London), **23,** 465 (1923).—Work on the development of refracs. from artificial sillimanite is in progress at U. S. Bureau of Mines, Northwest Experiment Station, Seattle, in coöperation with ceram. trade interests. The best compd. found is one a little richer in alumina than pure sillimanite. R. J. A.

Graphites for brass melting crucibles. R. T. STULL AND L. E. GEYER. *Metal Industry* (London), **23,** 466(1923); also *The Metal Industry* (N. Y.), **21,** 477–8(1923); (Abstr., U. S. Bur. Mines, *Rept.* **25,** 42(1923).)—Tests on bond clays had previously indicated that Mo. pot clay and Ill. kaolin were better than Klingenberg clay. Tests were next made to det. the value of American graphites for crucible making as compared with foreign ones. Mo. pot clay was used, and crucibles were made up with graphites from various domestic sources, and with Can., Ceylon, and Madagascar graphites. These crucibles were then tested in brass melting practice, and record kept of the failures. The most frequent cause of failure was pin holing, which usually developed at, or below, the slag line. Cracking was also a prominent cause of failure. The crucibles made of domestic graphite compared well with those made of the foreign. R. J. A.

Durability of refractories. W. J. REES. *Metal Industry* (London), **23,** 414–5 (1923).—(Abstr. of paper before Birmingham Met. Soc.) The selection and use of refrac. mats. cannot be placed on an adequate basis until phys. and chem. properties can be specified and tested in measurable quantities; this necessitates a clear understanding of the conditions that the mats. are called upon to meet. Failures of refrac. mats. are placed in 4 classes; *viz.*, (1) unsatisfactory qualities including lack of uniformity; (2) faulty selection; (3) faulty treatment due to accidents, carelessness or ignorance; and

(4) absence of factor of safety. Failures under the first two classes should be capable of being completely eliminated and those due to faulty treatment capable of elimination to a marked extent by proper training or a bonus to operators, based on the life of refracs. or pots. Durability is dependent upon 9 factors; *viz.*, (1) softening temp.; (2) mech. strength at normal and high temps.; (3) thermal or reversible expansion; (4) permanent expansion or contraction; (5) resist. to abrasion; (6) resist. to slag attack; (7) permeability to gases and vapors at high temp.; (8) resist. to abrupt changes in temp.; and (9) changes in properties after prolonged heating. In modern by-product coke ovens the mech. strength of silica bricks at high temps. is a consideration of importance to oven builders. The amplification of existing tests and provision of others is desirable Many structures collapse through careless heating and the use of unsuitable cements. Av. durability of refracs. is greater than formerly owing to scien. investigations, but good practice will be greatly promoted by close collaboration between makers and users. R. J. A.

An examination of refractories by the oxygen blow pipe. ALGERNON LEWIN CURTIS. *Trans. Ceram. Soc.*, **22** [2], 199(1922–23).—It is sometimes necessary to exam. quickly the refrac. qualities of raw mats. and to compare different mats. one with another during examn. In the ordinary method of test a prospective refrac. undergoes ultimate chem. anal., and if then considered satisfactory cones of the mat. finely ground are made up and exposed to varying temps. The result of such tests gives a percentage of total fluxes, and a number of distorted test pieces, which have undergone more or less change, according to the temps. at which they were exposed. Although the above combination of tests is an efficient one, the time and expense necessary to carry it out render large numbers of such tests a big undertaking. In order to save time when examg. small amts. of refrac. mat., a method was adopted for bringing into use the oxygen-coal-gas-blowpipe. The test piece was exposed to a strong fixed blowpipe flame and test pieces of a briquette nature were used. A camera was thought necessary. A crude wooden stand was improvised to carry the camera and span the lath bed holding the test piece. The idea was to mount in a microscopic table, in place of an Abbé condenser, a tube carrying a short focus telescopic objective of high order. A series of graduated diaphragms was provided in this tube. The function of the telescopic objective and diaphragms was to project an air image of part of the illumined test piece to the plane of the stage of a microscope. Instead of using a body tube in the microscope, a wooden front carrying a metal fitting was substituted, the wooden front forming part of the camera and the metal fitting for a microscopic objective. By inserting a microscopic objective in a metal fitting this objective became a photographic objective, and the air image projected by the telescopic objective became magnified by it, focusing being carried out with the ordinary rack mechanism of the microscope. The camera was designed to give suitable extensions and consequently increased magnification. In making a survey of the whole test, representing 56 test pieces from 7 different mats., and 7 pieces of Seger cones, it was seen that "surface attack" from heat and shrinkage could be readily studied; and those materials first affected by ht. are inferior to mats. which resist attack to the last. The best bauxitic clay tested was less liable to ht. attack than the Scotch fire clays, besides possessing less shrinkage. A distinct difference in quality of such bauxitic clays can be assumed from the difference shown in the heat attack of the three test pieces. Of the four Scotch fire clays, it was seen that one test piece had little claim to a place as a refrac. fire clay. The other fire clays can all claim to belong to the refrac. fire clay group, their chief detriment being high shrinkage. H. F. S.

Silica bricks for coke ovens. A. H. MIDDLETON. *Trans. Ceram. Soc.*, **22** [2], 169 (1922–23).—Under the foll. conditions, silica brick is recommended as a substitute for

quartzite: (1) In the case of new installations; (2) the renewal of walls where salty coal is used; (3) where ordinary coal is used, but the alterations or repairs are so extensive as to make it possible to alter the whole htg. arrangement as well as to replace the actual walls. The article points out briefly some of the advantages of a silica construction and deals in detail on one point in which silica bricks differ fundamentally from quartzite bricks, namely, their permanent expansion when heated to temps. at which ovens built of silica bricks are frequently operated. The raw mat. and the firing of the bricks are also discussed. H. F. S.

The behavior of fire clays, bauxites, etc., on heating. H. S. HOULDSWORTH, AND J. W. COBB. *Trans. Ceram. Soc.*, **22** [2], 111(1922–23).—Kaolin, a Dorset ball clay, Farnley fire clay, a Scottish fire clay, and Ayrshire bauxite clay were examd. It appeared that 7 definite shrinkage points existed between 15–1100°C for kaolin, *viz.*, at 530, 625, 700, 880, 950 and 1060°C, the clay having a very small rate of contraction at intermediate temps. when subjected to a prolonged htg., but expanding (reversible thermal expansion) when the htg. was more rapid. The shrinkages at 625, 700, and 780, were considerably smaller than those taking place at 530, 880, 950, and 1060°C. For Farnley fire clay pronounced shrinkage points occurred at 540, 880, 950, and 1080°C together with a slight shrinkage about 100°C. These changes were irreversible, as is seen from the cooling curve, which, however, shows the contraction on cooling between 600°C and 550°C due to the inversion of β to α quartz. Atlas fire clay behaved very similarly to the Farnley fire clay, giving marked irreversible shrinkages at 100–140°C, 540, 880, 980, and 1050°C with a rapid reversible expansion between 575° and 610°C due to the inversion of the free α quartz of the clay to β quartz. It will be seen that Ayrshire bauxite clay, an aluminous clay, differed from the siliceous clays examd. both in possessing a larger number of shrinkage points, *viz.*, at 100, 530, 620, 700, 880, 950, and 1015°C, and also in the larger contractions which took place at these temps. The shrinkage of clays is not a continuous process but one which takes place in a number of stages, each stage being completed at a definite temp. The shrinkages of considerable magnitude are, generally speaking, found at almost the same temps. in the different clays. Some points, such as the absence of the 530°C shrinkage in ball clay, have no doubt a significance, but one which can not be explained at present. Kaolin and all the clays and shales examd. show distinct heat absorption at a temp. of 500–530°C and heat evolution at a higher temp. This heat evolution occurs at a temp. of 1060–1130°C with pure alumina made by calcining aluminum nitrate at 700°C, but at a temp. lower to an extent of about 100°C with the bauxites and clays, possibly on account of the impurities associated with the alumina in combination or some form of solution effective for the purpose. Most of the mats. show heat absorptions at temps. below 500°C, presumably due to the loss of water from colloid subs. The phenomena observed with the clays are not primarily dependent on the presence of silica. They are noticeable with alumina and with a red bauxite practically free from silica, though the ht. evolution then took place at a higher temp. For some reason, although alumina calcined at 700°C and the bauxites and clays show marked heat evolution at about 1000°C as noted above precipitated alumina gave no sign of it. It may be that the change responsible for the ht. evolution had occurred with the pptd. alumina before it was heated in our app., but that with aluminum nitrate, or silicate the presence of other mat. associated with the alumina deferred the change. H. F. S.

Heat insulating materials for electrically heated apparatus. J. C. WOODSON. *Trans. Amer. Elec. Soc.*, **43,** 20 pp.(1923).—This paper is a general discussion of the subject. The author classifies processes into 5 temp. ranges between 0 and 1100°C and lists the insulating mats. applicable to each temp. range. The simpler formulas used in calcg. heat flow are given and discussed. Around 100 commercial insulating

mats. are listed with their important properties. All these insulators are made of about a half dozen different raw mats. in most of which the insulating property is caused by tiny entrapped dead air spaces in their structure. Larger air spaces between walls may tend to increase rather than decrease the heat loss, however, due to convection currents and radiation carrying the heat through them. Besides low heat condy., low sp. gr. and sp. heat, good mech. strength, etc., are desirable properties in insulating mats. In general, compared to electrical insulation our present mats. and data for applying them for the solution of heat insulating problems are still very imperfect. B. M. L.

Terra Cotta

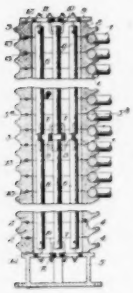
Industrial architectural practice. SYMPOSIUM. *Arch. Forum*, **39** [3], 83–151 (1923).—A whole number devoted to industrial architecture including following topics. Industrial architecture in concrete by CASS GILBERT. The choice of an industrial building site by MAURICE M. OSBORNE. General principle of planning. Choice of type of construction by JOHN R. NICHOLS. Fire prevention and protection and data on fire and accident prevention requirements by C. STANLEY TAYLOR. Roof types and roof surfaces by WALTER F. BALLINGER. Industrial flooring materials by CHARLES A. WHITTEMORE. Natural lighting by WM. R. FOGG. Welfare provisions by CHAS. L CLOSE. Plumbing by JAMES A. COTTER. Heating and ventilation by CHAS A. FULLER. Power provision and steam plant design by ALLEN HUBBARD. Artificial illumination by A. L. POWELL. Electrical power by JAMES A. MCHOLLAN. F. T. H.

Whiteware

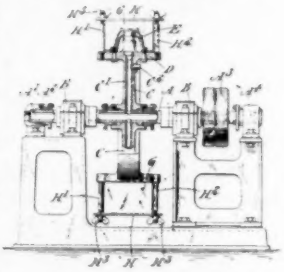
The production of porcelain for electrical insulation.—V. F. H. RIDDLE. *Jour. Am. Inst. Elec. Eng.*, **42**, 858–63(1923); see *Ceram. Abst.*, **2** [9], 199(1923); **2** [11], 258 (1923).—Methods of forming, drying and glazing the insulator shapes are described. Dust or semi-dry pressing is used on low-tension insulators such as switch bases, lamp sockets, etc. The dried filter press cakes are crushed, dampened, pulverized and pressed in steel molds. The density of this product is not so great as that formed from the plastic batch, but accurately sized, difficult shapes can be made. Throwing, jiggering and turning from pugged blanks are processes in which the body is shaped while in the plastic condition, and might be termed "plastic forming." Pieces formed in this manner are trued up while still damp but stiff enough to hold their shape. A special method in use at the author's plant for spark plug porcelains is known as dry process turning, and consists of revolving the bone-dry blank on a lathe, and facing it with a rapidly revolving grinding wheel. The drying shrinkage is eliminated by this process. The "hot press die" method is used on insulators with thin-walled petticoats. Here the plaster of Paris mold, having the shape of the outside or top of the insulator, is placed on a horizontally revolving wheel, the plastic clay being carefully pressed in so as to conform with the mold. A heated metal part is forced down upon the clay in the revolving mold, and shapes the spinning clay into proper form for the bottom of the insulator. The hot metal causes steam to be formed from the water in the plastic body, and this acts as a lubricant preventing the clay from tearing, and also making possible an extremely thin petticoat or wall. Casting from porcelain slip in plaster molds, a method widely used in the potteries, has been applied during the last five years to the forming of heavy insulators (high-tension). Density, uniformity and freedom from strain are the advantages conferred by this process. In the drying of elec. porcelain, modern methods of controlling humidity, temp. and circ. of the air, particularly as exemplified by the tunnel humidity drier, have reduced the time of drying of the larger pieces from weeks to days, and on all sizes of ware the losses have materially

decreased. Glazing of the insulators is described, and formulas given for a brown or "Albany slip" glaze and a clear white glaze. Low thermal expansion and high ht. condy. are valuable properties in both body and glaze, as they tend to minimize "crazing" and "shivering." In connection with glaze-fit, mention is made of the author's work on the application of tensile test specimens, in which it was clearly shown that when the expansion of the glaze departs considerably from that of the body, the tensile strength is less than normal. This may account for the failure of insulators in actual service, due to strains set up by fluctuations in temp. A. F. G.

PATENTS



Insulator. WALTER T. GODDARD. U. S. 1,474,256, Nov. 13. A column type insulator comprising a series of annular insulating units superposed one upon the other and each provided with a flange cut away to form a lip for receiving portions of successive convolutions of a conducting coil, interlocking means between adjacent units acting to prevent their relative movement, and tension rods formed of sections of insulating mat. and connecting the uppermost and lowermost units of the series and acting to hold all the insulating units in a state of compression.



Apparatus for casting or molding pottery and like articles. JOSEPH FORSYTH GIMSON. U. S. 1,474,432, Nov. 20. Apparatus for casting or molding pottery and like articles including in combination a hollow rotatable shaft, a hollow arm radiating therefrom and having its interior in communication with the interior of the shaft, an absorbent mold carried by the hollow arm, means for supplying the material to be treated to the interior of the shaft and thence through the hollow arm to the mold, and means for rotating the shaft, the moisture being removed from the mat. and absorbed into the mold under the action of the centrifugal force set up by the rotation of the app. as set forth.

Equipment and Apparatus

A new heat insulator, balsam-wool. HOWARD F. WEISS. *Concrete*, **23**, 149–50 (1923).—By disintegrating waste wood and rearranging the fibres so as to obtain a max. of dead air cells, there has been developed an insulating mat. which has a lower thermal conductivity than Balsa, the lightest natural wood. Thickness (inches) required to equal $^1/_2$ in. of balsam-wool: balsam-wool, 0.50; sheathing lumber, 1.58; common brick, 8.00; sheathing paper (solid), 1.59; lime plaster or stucco, 17.00. F. T. H.

A thermostat for moderate and high temperature. J. L. HOUGHTON AND D. HANSON. (Collected Researches.) *Natl. Phys. Lab.*, **15**, 53–65(1920); *J. Inst. Metals*, **14** (1915) and **18** (1917).—Describes an air bulb thermostat made of glass or fused silica, the expansion and contraction of the air making and breaking a mercury contact which operates a solenoid controlling the resistance in the fur. circuit. E. S.

A carbon tube furnace for testing the softening points and compressive strengths of refractories. E. GRIFFITHS AND E. A. GRIFFITHS. (Collected Researches.) *Natl. Phys. Lab.*, **15**, 19–28(1920); *Trans. Faraday Soc.*, **12**(1917).—A carbon tube resistance furnace packed with zirconia and magnesia using N to maintain neutral atmosphere. The load is applied by means of springs and transmitted to the specimen through a yoke and carbon block. E. S.

Pyrometer standardization. E. GRIFFITHS AND F. A. SCHOFIELD. (Collected Researches.) *Natl. Phys. Lab.*, **15**, 31–47(1920); *Trans. Faraday Soc.*, **13**(1919).—A review of the methods for standardizing various types of pyrometers. E. S.

An economical furnace for fusions. POZZI. *Corr. dei Cer.*, **4**, 10(1923).—A fur. constructed for the use of coal as a fuel in the smelting of frits working in a continuous manner. It is designed with a feed of the mix in at one side and the flow of frit out on opposite. The fur. requires but 300 kgs. of coal a day and the product is completely fused and the temp. possible to reach is 1300°C. The opern. is rapid and a regenerative system is used with a very economic production of smelter. No drawing of fur. given and no amt. of mat. produced. S. S. C.

The strong arm of industry. ANON. *Cement & Eng. News*, **35** [9], 26–9(1923).—A discussion of modern power shovels, giving opinions on relative merits of steam, elec. and gasoline-elec. types. It is conceded that elec. and gasoline-elec. are most economical and advantageous for small installations, while steam is still best type for the larger shovels. F. T. H.

Automatic burner control. ANON. *The Foundry*, **51** [23], 968(1923).—Describes the F. J. Ryan & Co. automatic temp. control for oil and gas fired fur. The unit consists of a valve operg. in conjunction with a magnet, the movement impulse originating in a thermocouple within the htg. chamber, and connected through a recording pyrometer and control panel. It is adaptable to high or low press. burners. Illus. M. E. M.

Experimental study of ball-mill grinding. D. H. FAIRCHILD. *Eng. & Min. Jour. Press*, **116** [20], 845–6(1923).—F. studied the action in ball mills with heavy glass end plates by observation and by motion pictures. The factors in ball-mill action are impact crushing, attrition and dead wt. Impact crushing is by far the most important. In the usual ball mill of circular section this action takes place largely only in the upper surface zones of the charge, with large zones at the center and next the walls comparatively inactive. The circular section gives little wear on linings and best distribution of loading, but varied forms may be developed that will cause "a more rapid change of mill content" and "more effective agitation within the ball mass." B. M. L.

Rubber lining for ball mills. A. B. PARSONS. *Eng. & Min. Jour. Press*, **116** [12], 489–90(1923).—Originating in observation of the remarkable wearing power of automobile tires over rocky roads, the idea of using similar rubber linings for ball mills has been developed and applied successfully at the Nipissing Mining Company's plant near Cobalt, Ontario. The idea has been patented. The rubber used is not hard but rather soft, tough and well vulcanized. A 4 x 20 ft. mill, charged with 20 tons of 1.25″ iron balls and used for regrinding sand from a Dorr classifier, was lined with a $^5/_8$″ layer of rubber in Jan., 1923. After steady use it was still in first class condition in August, 1923. The cost of a $^5/_8$″ rubber lining is slightly less than that of a 2″ iron lining. Such a rubber lining is much easier to install or replace, has about $^1/_{20}$ the weight of the iron and will last at least as long and probably much longer. The rubber lining also gives much increased grinding capacity and somewhat less ball consumption. B. M. L.

A thermopile for measuring radiation. W. J. H. MOLL. *Proc. Phys. Soc. London*, **35**, 257–60(1923).—The thermopile is designed to be quick-reading, sensitive, and free from zero-errors. The cold junctions are in contact with metal masses which keep down their temp., and in order that the hot junctions may have small heat capacity the bimetallic strips composing the thermopile are made of plates of constantan and manganin, Ag-soldered along an edge, rolled in a direction parallel to the edge into thin foil, and then cut into strips perpendicular to the edge. C. C. V. V. (*C. A.*)

Electric furnace operation. ANON. *Elec. World*, **82**, 727(1923).—Discussion of costs, linings, suitable size, etc. by a number of elec. furnace experts. C. G. F. (*C. A.*)

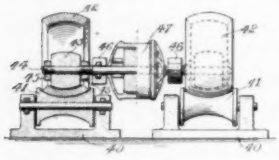
Progress in the manufacture of steel in the electric furnace. CLAUSEL DE COUSSERGUES. *Rev. métal.*, **20,** 417–22(1923).—Discussion of the advantages of the elec. furnace with a description of the various types and their merits and disadvantages.
A. P.-C. (*C. A.*)

A new colorimeter with absolutely symmetrical rays. K. BÜRKER. *Z. angew. Chem.*, **36,** 427–9(1923); 3 cuts.—An immersion colorimeter, mounted on a stand like a microscope, the rays from the 2 tubes being thrown on the same field for comparison. Directions for operating are given. J. H. M. (*C. A.*)

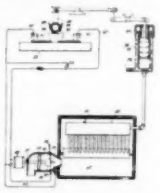
New liquid manometers and their use in heating and ventilating practice. E. NICKEL. *Feuerungstechnik*, **11,** 137–40(1923).—The form of draft gage described has a cylindrical well with axis horizontal, so that the gage can be used at different inclinations without affecting the zero reading. E. W. T. (*C. A.*)

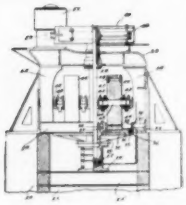
PATENTS

Roller-grinding machine. JOSÈ FERENCZ. U. S. 1,475,693, Nov. 27. A rolling mill comprising drums having open ends mounted for free rotation around a common horizontal axis, a grinding roller in each drum held by gravity in contact with the inner periphery of its respective drum, a shaft extending through said open ends and upon which said grinding rollers are rigidly secured, oscillatory guide arms for said shaft permitting radial displacement of the grinding rollers in relation to said axis, means for rotating said shaft with said grinding rollers; said rotating means including a motor suspended from said shaft, the weight of said motor, shaft, and grinding rollers being sustained upon the inner periphery of said drums; whereby a constant pressure is exerted against said drums independent of the revolving speed of the rollers.



Controller for fuel-oil burners. FINN S. HUDSON and EDGAR G. RHOADS. U. S. 1,475,433, Nov. 27. In a device of the class described, a steam-generating boiler having a fire-pot, a fuel-oil atomizer, an air-blower to deliver the fuel to the fire-pot, an elec. motor for the blower, an electric circuit for the motor having a switch, a cylinder having a piston and communicating with the boiler below the piston, a spring restraining the piston in its cylinder, an adjustable plate to vary the tension of the spring, a cap on the piston having an adjustable pin, and a lever coöperating with the pin and switch to open the latter when the piston is protracted and to close it when the piston is retracted.



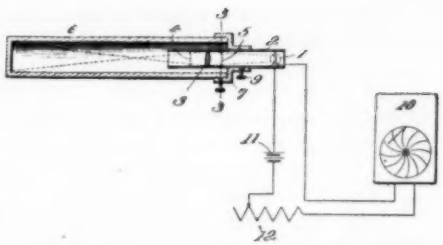


Dry pan. DAVIS BROWN. U. S. 1,476,143, Dec. 4. In an improved dry pan grinding mach., the combination of a vertically mounted rotatable pan, a rim on the periphery of said pan, a stationary rim located above and defining, with said first rim, an opening through which ground mat. may pass, and means for moving said rims relatively to each other to vary the width of said openings.

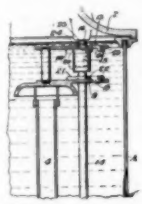
Electric resistance element. FRANK A. FAHRENWALD. U. S. 1,475,942, Dec. 4. An elec. resist. element made of an alloy of iron from about 16% to about 20% of chromium and about 1% to about 3% of manganese.

Apparatus for measuring high temperatures. JULIAN L. SCHUELER and CHESTER A. KELLOGG. U. S. 1,475,365, Nov. 27. In device for measg. high temps., in combination, a tubular body, a light sensitive cell in said body, a lens in said body, and means

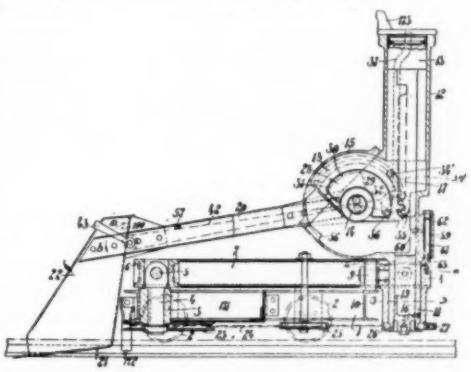
connected with said tubular body arranged to exclude light interfering media between said means and said cell and when subjected to ht. changing in degree of intensity of color which change affects the resist. of said cell.

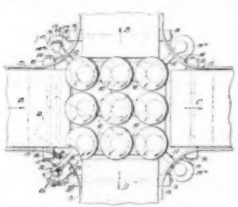


Liquid-measuring apparatus. GEORGE W. MACKENZIE. U. S. 1,475,844, Nov. 27. Locking mechanism for a liquid measg. app. of the class shown consisting of a vertically maintained rising and falling float, a vertically and annularly movable element having locking abutments for engagement by the top and bottom of the float, and means for locking the movable element at varying heights. In a liquid measg. app. having a vertically and rotatably movable supply and return conduit, a vertical guide rod, a freely movable float thereon, float-engaging plates connected with the conduit extending below and above the float in slotted engagement with the guide rod and having annularly arranged locking abutments for engagement by the float, and means for locking the conduit at varying heights.



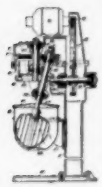
Loading machine for ores and the like. THORE ROBERT EUGEN RUNDQVIST. U. S. 1,475,888, Nov. 27. A mach. for loading ores and the like into cars on mine tracks, comprising in combination a carriage frame, wheels for supporting said frame, another frame, pivotally mounted on said carriage frame to sweep horizontally thereover, an upstanding power motor, pivotally mounted at the free end of said other frame to rotate around a vertical axis in relation thereto, a horizontal crank shaft of said motor, arms attached to said shaft, and a bucket carried by said arms. In a machine for loading ores and the like into cars on mine tracks, the combination with an upstanding cylinder, of a piston therein, means for introducing motive power on the upper side of said piston, a piston rod, a crank shaft, arms attached to said crank shaft, a bucket carried by said arms, and a connection between said piston rod and said crank shaft to cause the said bucket arms to swing upwardly upon the downward movement of the piston.



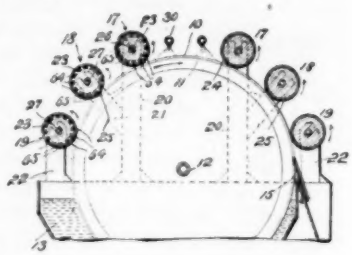


Transfer device for conveyers. SAMUEL OLSON. U. S. 1,475,962, Dec. 4. In combination with a plurality of conveyers arranged with adjacent termini, a transfer device comprising a group of driving members interposed between said termini and all mounted to rotate about axes slightly inclined from strictly vertical direction for exposing upwardly a limited portion of the circular driving surface of each member which extends in a plane substantially perpendicular to the axis of rotation of the member.

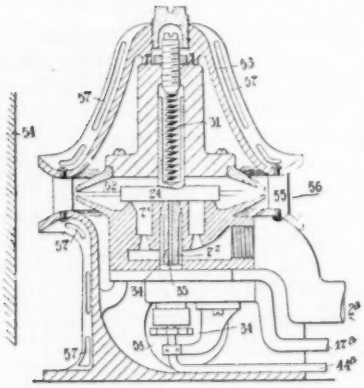
Beater. FREDERICK WESTERMAN. U. S. 1,475,978, Dec. 4. A beating app. comprising a receptacle having a cover provided with a central opening, a beater shaft set oblique to the vertical and entering the receptacle through the opening in the cover, a paddle on the shaft and in the receptacle, and means above and independent of the cover for supporting and rotating the shaft on its axis and also for bodily moving the shaft in a conical orbit having its apex substantially at the opening in the cover.



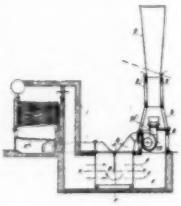
Filter. LOUIS C. ROLLS. U. S. 1,475,244, Nov. 27. A filter having, in combination, a continuously moving filtering surface, means for creating a vacuum at the filtering surface, means for covering the filtering surface with mat. to be filtered, means for supplying wash fluid to the surface of the mat., and a series of rolls mounted to rest upon the surface of the mat. and interposed in the path of travel of the fluid, all said rolls, except the last one, being provided with channels for the passageway of the fluid past the rolls.



Mechanical vaporizing oil burner. JAMES WALLACE TYGARD and ELIZABETH ANN TYGARD. U. S. 1,473,891, Nov. 13. In a mech. vaporizing oil burner for the production of mixtures of air and liquids, the combination of a hollow fixed member, a vibrating member located within the body of the fixed member in such manner as to divide it into substantially two compartments, whereby the movement of the vibrating member opens communication between said compartments when the vibrating member is actuated either by vacuum or pressure and automatically closes communication when pressure is released or vacuum broken, regulatable means for controlling the action of the vibrating member, means whereby a regulatable amount of gaseous or liquid fuel and air is admitted to one compartment, means whereby their incorporation into a finely pulverized homogeneous combustible or stable vaporous mixture is effected when passing from one compartment to the other, a suitable refrac. or protective enclosing envelope or cover having suitable passages for the introduction of cooling mediums and suitable annular openings through the side of said cover adapted to conduct the combustible vaporous mixtures generated in the carbureting device to the refractory wall or lining against which they burn when ignited.



Induced and forced draft apparatus. EMILE PRAT. U. S. 1,473,870, Nov. 13. An app. for the production of draft in fur. by simultaneous induction and blowing, comprising a chimney flue, a casing arranged within the chimney flue and divided into two compartments having independent central inlets and peripheral outlets, a rotatable shaft in said casing, bearings supporting said shaft at each end on opposite sides of the flue, fan sections carried by the shaft and operating in the respective compartments, a delivery nozzle on one of the sections



opening into the chimney at the axes thereof, said fan sections communicating with the interior of the chimney flue and being transversed by only a portion of the combustion gases from the fur. and adapted to produce a draft by ejector action in the chimney, the other fan section having its inlet in communication with the atmosphere and adapted to direct an air blast to the grate of the fur. See *Ceram. Abs.*, **2** [11], 263(1923).

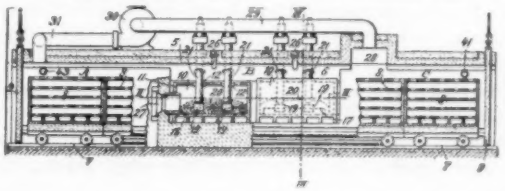
Kilns, Furnaces, Fuels and Combustion

Use of pulverized coal in open-hearth furnaces. R. H. LOWNDES. *Mech. Eng.*, **45** [11], 651–2(1923).—The cost of producing steel in open-hearth fur. burning pulverized coal at the Atlantic Steel Co. is greater than when natural gas is used. The life of the checker work is shortened by the use of pulverized coal. In a report on Pulverized Coal Systems in America, compiled by Leonard C. Harvey, and published in London in 1919, under the heading "Opinions of Users" occurs the following statement: "Have found the average life of checkers for various fuels in the open-hearth fur. to be: Natural gas, 1000 hts.; producer gas, 350 to 500 hts.; oil, 350 to 500 hts.; and pulverized coal, 225 to 250 hts. C. J. H.

Symposium on heat transfer. ERLE M. BILLINGS. *Science*, **58** [1508], 416 (1923).—A symposium on ht. transfer will be held at the spring meeting of the Amer. Chem. Soc. W. H. Adams, of the Mass. Inst. Tech., is chairman of this symposium. C. J. H.

PATENT

Tunnel kiln. GEORGE HILLARD BENJAMIN. U. S. 1,474,616, Nov. 20. A tunnel oven comprising a main chamber through which goods to be heated can be caused to travel; a htg. chamber on each side of the main chamber, structurally independent of the side walls and roof of the chamber; and means in each chamber for converting and transmitting elec. current into ht.



Geology

The superiority of British china clay. ANON. *Can. Min. Jour.*, **44**, 826–7(1923).—The world is still largely dependent on the unlimited supplies of china clays from Cornwall, England, which heads the list both in quantity and quality of production. Gradually increasing competition is noted from many foreign sources. Search for new deposits is active in Canada, U. S., and China. Canada has a good deposit near St. Remy D'Amherst, near Huberdeau, Quebec. It may ultimately supply all the needs of Eastern Canada. A deposit near Foochow, China, close to the South Manchuria Railway, is producing for export about 70,000 T. per annum. The U S has relatively few deposits of good china clay so far discovered, which are chiefly in the S. states. B. M. L.

Notes on Canadian minerals—allanite, axinite, columbite, and sillimanite. T. L. WALKER AND A. L. PARSONS. *Univ. Toronto Studies, Geol. Surv.*, No. **16**, 29–37 (1923).—Allanite is described from pegmatites at (1) Seguin Falls, Ont., and (2) Labelle Co., Que. They differ considerably in composition. Analyses (E. W. Todd):

	SiO_2	ThO_2	CaO	FeO	MnO	MgO	Al_2O_3	Fe_2O_3	Ce_2O_3, etc.	Y_2O_3, etc.	H_2O	Sum
1	31.88	0.44	12.94	9.56	0.74	1.03	16.66	4.91	19.58	1.64	1.33	100.71
2	31.94	0.52	14.76	12.13	1.10	0.32	18.18	3.80	13.44	0.76	2.99	99.94

Sp. gr. (1) 3.658, (2) 3.279; n (1) 1.735, (2) 1.650; (1) birefringence 0.01, (2) isotropic. Axinite from Marmora Twp., Hastings Co., Ont. is found in a hornblende schist. Analysis (Todd): SiO_2 41.46, B_2O_3 4.88, Al_2O_3 19.94, Fe_2O_3 0.96, FeO 4.56, MnO 5.44, CaO 19.57, MgO 1.99, H_2O 1.61, sum 100.41, sp. gr. 3.221. The formula $13RO.B_2O_3.10SiO_2$ is suggested for axinite. Columbite. Four analyses (Todd) are given: (1) crystals, Lavers Mine, New Ross, N. S.; (2) Hazaribagh, Bengal; (3) Lyndoch Twp., Renfrew Co., Ont.; (4) massive with visible rutile, Hybla, Ont. All are from pegmatites.

	Cb_2O_5	Ta_2O_5	TiO_2	SiO_2	SnO_2	MnO	FeO	Sum	Sp. gr.
1	63.08	14.48	1.47	0.34	0.22	10.44	10.46	100.49	5.613
2	65.49	13.89	0.66	0.10	0.22	14.12	5.59	100.22[1]	5.563
3	55.79	15.21	5.19	1.28	0.56	10.24	10.90	100.14[2]	5.431
4	66.60	1.74	5.22	0.64	0.36	9.06	8.61	100.01[3]	5.147

[1] Also 0.15 CaO. [2] Also 0.15 CaO, 0.82 rare earths. [3] Also 1.25 ZrO_2, 3.44 ThO_2, 1.68 rare earths, 1.41 H_2O.

Sillimanite crystals, up to $^1/_2$ inch long, occur in a gneiss at Romaine, Que. The mineral is colorless and transparent. Analysis (Todd): SiO_2 36.70, Al_2O_3 62.73, Fe_2O_3 0.63, sum 100.06; sp. gr. 3.209. E. F. H. (*C. A.*)

Chemistry and Physics

The oxides of iron. J. D. FERGUSON. *Jour. Wash. Acad. Sci.*, **13** [13], 275–81 (1923).—(1.) The iron phase in the system (H_2, H_2O, Fe, FeO) was studied in an elec. htd. tube fur. to det. the quantities of oxygen present. Materials used were electrolytic iron and piano wire. The temps. varied from 750°C to 980°C. Six runs were tabulated. Results indicated that the system does not contain appreciable quantities of O_2. (2.) The transition temp. of the ferrous oxide phase was studied and found to be somewhat below 577°C. The presence of ferro-ferric oxide in soln. in the ferrous oxide lowers this temp. (3.) Equilibrium constants at 750°C were checked by the stream method. Values were obtained indicating that the oxidation starts with a H_2O/H_2 ratio slightly less than .54. This work checked Chaudron's figures very well. F. C. F.

The thermal conductivity of materials employed in furnace construction. E. GRIFFITHS. (Collected Researches.) *Natl. Phys. Lab.*, **15**, 1–15(1920); *Trans. Faraday Soc.*, **12** (1916).—Gives a critical summary of earlier determinations of conductivity of fire clay, silica and magnesite brick. In G.'s method the test brick of stand. size is htd. on one face by a bath of molten tin in expts. up to 450°, and above that temperature by pressing it against a flat iron plate forming a portion of the wall of a large uniformly heated muffle. Results by the 2 methods agree though the metal bath gives greater accuracy due to more uniform htg. Temps. are observed by means of thermocouples and ht. transfer by means of a flow calorimeter provided with a guard ring to protect the calorimeter against sharp temp. gradient. The following values were obtained for conductivity in C. G. S. units: Diatomaceous brick 105° to 502° mean temp., 0.000310 to 0.000461; matted slag wool, 194° to 476° mean temp., 0.000191 to 0.000342; magnesia pipe packing 310° mean temp., 0.00022. E. S.

Properties of powders. VI. Compressibility of powders. E. E. WALKER. *Trans. Faraday Soc.*, **14**, 55-73(1923).—A method devised for measg. the resist. of powders to compression by static load and blows from a falling wt. Materials used were Pb, NH_4NO_3, NaCl, TNT, $CaCO_3$. Three classes of curves developed showing progress of compression varying with the type of mat. Microscopic examn. shows the extent of the deformation of the crystals. (More work could be done on this.) F. C. F.

Properties of powders. VII. Distribution of densities. E. E. WALKER. *Trans. Faraday Soc.*, **14,** 55–80(1923).—Local d. in columns of compressed powders studied. Various methods of packing compared. Some discussion of the effect of compression and d. on the cohesive power of the powder. F. C. F.

Simple method of determining apparent densities. KENNETH K. DODDS. *Chem. and Met. Eng.*, **29,** 324–5(1923).—Density is defined as the wt. (or mass) per unit volume, or wt. divided by vol. The vol. of continuous, impervious solids is readily found by the loss of wt. when suspended in water, since, by Archimedes' principle, the loss in wt. equals the wt. of an equal vol. of water. We have, then, $D = W_1/(W_1 - W_2)$, taking the d. of water as unity, where D = density, W_1 = wt. in air, W_2 = wt. suspended in water. Porous bodies cannot be so treated, owing to absorption of water, which causes the suspended wt. to be too great by an amount equal to weight of water thus absorbed. This objection could be overcome by weighing body after immersion. By subtracting the suspended wt. from the satd. wt., the absorbed water cancels out, leaving the bulk vol. Thus, $D = W_1/(W_3 - W_2)$, where W_3 = satd. wt. This suggests the method of measg. porosity by boiling in water, but the above process unfortunately is not applicable to the detn. of porosity. Numerical data is given showing apparent d. of coke, carbon, and various types of brick as detd. by the above method and by boiling under reduced pressure for 1 hr. The results agree to several units in the second decimal place. A. F. G.

Different types of plasticity of clays and kaolins. M. A. BIGOT. *Ceramique*, **26,** 194–8(1923).—B. divides the bonding power of kaolins and clays into 4 classes as follows: (1) Colloidal bonding power caused by extremely fine mineral particles; (2) lamellar bonding power caused by plates of kaolin, mica, etc., in clays; (3) organic bonding mats. as glue; and (4) fibrous bonding properties such as is caused by adding fibrous mat. to a plastic clay. The organic and fibrous bonding mats. make the clay more workable and cause it to be more resist. to breakage in the dry state. The lamellar bonding mats. cause the clay to be more workable in the plastic state and also impart strength to the dry clay. The colloidal bonding properties play an important rôle in ceramics. Those liquid, physical and chem. agents which develop the colloidal properties of clays are known as peptising agents. Those which destroy the colloidal properties are known as peptising agents. Clays and kaolins are more or less colloidal and are partly peptised by water. Plastic clay consists of 2 kinds of subs. One kind absorbs the water and swells and is peptised by the water. The other mat. is too coarse to become peptised and hence is simply coated with water, and does not swell. Petroleum when added to dry powdered clay and pressed into bricks at a high pressure does not develop strength in the clay upon drying but causes the clay to crumble to a powder. This is considered a pektising agent. On drying plastic clay it slowly shrinks and becomes hard. The plastic clay possesses colloidal properties and these colloids become pektised by driving the water from the colloid. The colloids thus pektised give strength to the clay. Plasticity, drying shrinkage, and strength are greatest for clays having the highest colloidal content. A thorough pektisation of the colloids of clay does not take place upon drying. A dry clay adsorbs moist. from the air, this being more from moist air than from dry air. Kaolins washed from disintegrated rocks of sand and mica do not have much bonding power. Clays removed from wet banks are on the other hand very plastic provided they are not too rich in sand and mica. All clays and kaolins contain organic matter and bacteria. Under the influence of time, wetness, and bacteria the colloidal portion of clays are increased. The Chinese allow their clays to remain in damp cellars for 100 yrs. before using them for pottery. By pressing and heating a pektisation of the colloid takes place. It was found that extremely plastic clays became insol. in water after heating to 400°C. Lean clays and kaolins first became insol. in water after

heating to 500°C. Slaty clays first became insol. after heating to 600°C. Hot water produces less pektisation than press. and heat. Slaty clays are very difficult to pektise especially if they contain bituminum. If a bituminous slaty clay is pektised by heating to 600°C and then is treated with chemicals to remove the bituminous matter the clay becomes colloidal again and becomes pektised at 400°C instead of 600°C as was necessary for the bituminous clay. B. also detd. the effect of colloids in clay upon the resist. of the ware made from it to freezing. He used a brick clay containing considerable sand and mica as impurities. Three types of bodies were studied. (1) The powdered clay was heated to 150°C and pressed into bricks at this temp. with a press. of 700 kg./cm.^{2} (2) The powdered clay was dried at room temp. and mixed with 4% water and pressed at 700 kg./cm.^{2} (3) The clay was mixed to normal consistency with water and pressed into brick at 15 kg./cm.^{2} Separate samples of each of the 3 groups were fired at 900° and 1000°C. These bricks were saturated with water and frozen at −15°C for 4 hrs. This was repeated until the brick disintegrated. The results showed that bricks of groups 1 and 2 failed before the tenth treatment while those of group 3 withstood the tenth treatment. The brick of group 1 had practically no colloids but owing to the high pressure which it received it withstood the freezing test 4 hrs. The trial pieces of group 2 developed some colloids and this together with the press. caused it to withstand the freezing treatment for 8 hrs. In group 3 the max. amt. of colloids were developed and hence this brick withstood the freezing treatments longest. The brick of groups 1 and 2 had a very good appearance and were slightly less porous than those of group 3 but in spite of their lower porosity they failed in the freezing tests due to lack of pektised colloids. In making this clay into bricks and roofing tile it was found that a product most resist. to freezing could be made by making these from plastic clays. By using the dry press process about 6 hrs. can be saved in the time of manuf. but the product made in this manner is not resistant to freezing unless made from an exceptionally plastic clay. It is true that the bricks can be made more resist. to freezing by firing them to a higher temp. but by so doing the color is often spoiled and the fuel consumption increased. If a clay is dried in an atmos. satd. with H_2O a vapor press. is exerted in the clay which causes more colloids to become peptised and hence in drying develop greater strength. Ware dried in moist air becomes pektised at 400° to 450°C and after firing at 900°C is very resist. to frost. The drying in moist air requires 48 hrs. at 45°C and not quite 8 hrs. at 90°C. H. G. S.

The plasticity of crude gum. MARZETTI. *Giorn. Chim. Ind. ed Appl.*, **5** [7], 342 (1923).—The plasticity is measured in an app. by which temp. and press. are regulated and the rate of flow through an aperture measured during time intervals. By this means the control of the heating of gum and an idea of the effect of heat on it is obtained. Drawing of apparatus is given. S. S. C.

Rapid technical determination of Fe_2O_3 and Al_2O_3 LUCHESSI. *Giorn. Chim. Ind. ed Appl.*, **5** [1], 12(1923).—The ppt. of hydrate of Al_2O_3 and Fe_2O_3 obtained with NH_4OH in presence of NH_4Cl is dissolved in $N/2$ H_2SO_4. The excess of acid is titrated with NaOH $N/2$ using methyl orange as an indicator. Difference of H_2SO_4 thus is left as combined with Al_2O_3 and Fe_2O_3. After addition of concd. H_2SO_4 and reducing with H_2S the Fe_2O_3 is gotten with $N/2$ $KMnO_4$. By calcn. the acid combined with Fe_2O_3 is obtained and Al_2O_3 is derived in like manner. S. S. C.

The ternary system of Al, Zn, Sn. LOSANA AND COROZZI. *Gazz. chim. ital.*, **53** [8], 546(1923).—The binary system of Al–Sn, Al–Zn, Zn–Sn were investgd. and curves given showing eutectic points. Al–Sn is of simple type with a eutectic at 0.6% Al and 229°C. Sn–Zn system had eutectic at 197°C and 9.7% Sn with 0.5% α-Zn and up in solid soln. while at 49% Zn a conversion of Zn takes place. The Al–Zn system is complicated with solid solns. of the various forms of Al and Zn. The ternary system

has a eutectic at Al 1.46%, Zn 10.37%, Sn 88.17%, and 194°C. Diagram of system given and microphotographs of eutectic. S. S. C.

The ternary system of S, Se, Te. LOSANA. *Gazz. Chim. Ital.*, **53** [6], 396(1923).—Binary system of S–Se, Se–Te, S–Te were run. A eutectic of S–Se at 66% S and 104°C was found. Se–Te did not give a point and S–Te gave one at 109°C. 7% Te with a solid soln. present. No eutectic was formed in the ternary system. A diagram of system and microphotographs are given. S. S. C.

The ternary system of Al, Zn, Sn. E. CREPAZ. *Giorn. Chim. Ind. ed Appl.*, **5** [6], 285(1923).—A study of the ternary system of Al–Sn–Zn was made and a confirmation of the results obtained by other men. Eutectic of Al–Sn, Al–Zn, Zn–Sn systems were found. A eutectic of the ternary system found at 86Sn, 13Zn, 1Al and 210°C. Microphotographs of various points in the study are shown and tables of compns. of the system run are given with curves of binary and ternary systems. S. S. C.

The influence of some compounds on the transformation of quartz. PARRAVANO AND TURCO. *Gazz. Chim. Ital.*, **53** [4], 249(1923).—A rev. of work on increase of transformation of quartz by certain subs. is made. Expts. on ganister rock are made by the addition of various amts. of Fe_2O_3, P_2O_5, B_2O_3, CaO, WO_3 up to 1.5% and the samples burned to cone 15 and 18. The d. of all obtained and results are given showing in nearly all some effect. It was found that 3% of Fe_2O_3 did not greatly affect the refractoriness. B_2O_3 hastens the reaction. Microphotographs of the various mixts. and temp. show the amt. of conversion. Fe_2O_3 forms compd. with the SiO_2 and Al_2O_3. At cone 18 all the quartzite is converted to trydimite and cristobalite, with the trydimite being bonded by the cristobalite. S. S. C.

Effect of size and physical properties on the heat absorption of checkerbrick. O. A. HOUGEN AND DAVID H. EDWARDS. *Chem. and Met. Eng.*, **29**, 800–3(1923).—The transfer of ht. from the surface of the brick to its interior is computed by the aid of an equation taken from the mathematical theory of ht. conduction, connecting the heat flowing through 1 sq. cm. of surface in a given time, the thickness, thermal condy., sp. ht., apparent density, and temp. of surface. This applies to the case of parallel walls held at a constant temp. (Lord Kelvin's "infinite slab"), but, by means of Langmuir's shape factor, may be applied to the case of checkerbrick Curves are drawn showing rate of absorption of heat by silica brick of varying thickness ($2^1/_2$ in. to 10 in.), also by various refract. for a thickness of $2^1/_2$ in. Tables are computed showing time required by the different mats. to absorb 95% of the total heat, and the max. period of regenerative reversal. It appears that magnesia would make the most desirable checkerwork, were it not ruled out by its tendency to spall, as it absorbs 50% more heat than fire brick, and its reversing time (7 min.) is $^1/_3$ that of fire brick (21 min.). Carborundum ranks next, but when the reversal time is longer than 20 min., it offers no advantage over fire brick. Since the function of checkerwork is to store up a large amt. of ht. quickly, it is obvious that high thermal condy., d. and sp. ht. are all desirable qualifications, whereas materials of the insulating variety such as Sil-O-Cel should be avoided. A. F. G.

Some changes taking place in the low-temperature burning of Stourbridge fire clays. C. E. MOORE. *Trans. Ceram. Soc.*, **22** [2], 138(1922–23).—Three definite "critical ranges" are to be found in Stourbridge fire clay at temps. approximating to 700°C, 920°C, and 1030°C. The changes take place in all the clays of the series and at similar temps. in each. The magnitude of the changes and particularly of the 700°C and 900°C changes decreases with the alumina content. The examination of the changes in properties at these temps. gives results inexplicable by the kaolinite theory. The hexite-pentite theory provides a "clay substance" agreeing well with analytical results and with the geology of the deposits. The transformation of this "clay substance"

to an isomeric form gives a complete explanation of the changes in properties at 720°C and the critical ranges surrounding it. The polymerization of the isomer completely explains the 920°C change with the exception of the porosity results. The 1030°C change is probably of a purely mechanical nature and requires investigation. The hexite-pentite theory gives a more complete explanation of the processes involved than any other, and is to be regarded as the most successful theory of "clay substance" in its application to Stourbridge fire clay. H. F. S.

Measurement of the indices of refraction of a solid by immersion in a liquid heated to a determined temperature. P. GAUBERT. *Bull. soc. franc. mineral.*, **45,** 89–94 (1922).—The Becke or Schröder van der Kolk method for the petrographical microscope is used. The solid whose n is to be detd. is placed in a hot liquid of slightly lower n. As the liquid cools its n becomes greater and finally equals that of the solid. By noting the temp. at which this occurs an exact detn. of n may be made. There is a list of suitable media, with their n at room temp., and the value dn/dt from which n at any temp. up to the b. p. may be calcd. E. F. H. (*C. A.*)

Cohesion, hardness and toughness. P. LUDWIK. *Z. Metallkunde*, **14,** 101–10 (1922); *J. Inst. Metals*, **28,** 572. H. G. (*C. A.*)

The quantity and composition of colloid clay in kaolin from Meissen. ALBERT VASEL. *Kolloid.-Z.*, **33,** 178–80(1923).—The Meissner kaolin contained at least 3% of colloid clay whose compn. corresponded to the theoretical formula $Al_2O_3.2SiO_2.2H_2O$. Lime and magnesia did not enter into the compn. of the clay substance but were adsorbed by the colloid particles. H. M. McL. (*C. A.*)

The determination of chromium in the presence of organic matter. GEORGE GRASSER. *Z. Leder-Gerberei-Chem.*, **2,** 185–8(1923).—Several methods for the destruction of org. matter in chrome liquors were tried. It was found that oxidation with either $KClO_3$ or fusion with KNO_3 and subsequent titration with $Na_2S_2O_3$ gave good checks with the gravimetric detn. of Cr. Where $KMnO_4$ was used, variable results were obtained. E. J. K. (*C. A.*)

A new volumetric method for the determination of nickel. G. SPACU AND R. RIPAN. *Bul. soc. stiinte Cluj*, **1,** 325–31(1922); *Chem. Zentr.*, **1923,** II, 380.—The method is based on the complete pptn. of a sky-blue complex compd. of Ni from aq. soln. by K or NH_4 thiocyanate in the presence of C_5H_5N, thus: $NiX_2 + 4C_5H_5N + 2NH_4CNS \longrightarrow [Ni(C_5H_5N)_4](CNS)_2 + 2NH_4X$. An excess of 0.1 N NH_4CNS is added in the presence of C_5H_5N to the neutral or slightly acid Ni soln. and the NH_4CNS not reacting is titrated back with 0.1 N $AgNO_3$, $(NH_4)_2Fe(SO_4)_4$ being used as indicator. 2(CNS) corresponds to 1 Ni. Comparative expts. by electrolysis showed max. deviations of 0.11%. C. C. D. (*C. A.*)

The crystal structure of strontium selenide. MABEL K. SLATTERY. *Proc. Am. Phys. Soc.*, **1922;** *Phys. Rev.*, **20,** 84(1923).—SrSe has a simple cubic lattice with d = 3.10 Å. The unit cube has a side 3.10 Å, alternate corners being occupied by Sr and Se atoms. S. K. A. (*C. A.*)

Crystal structure of vanadium, germanium and graphite. A. W. HULL. *Proc. Am. Phys. Soc.*, **1922;** *Phys. Rev.*, **20,** 113(1922).—V has a body centered cubic lattice, side 3.04 Å; distance between nearest atoms, 2.63 Å; ideal d., 5.76. Ge has the same structure as the diamond. The side of the unit cube is 5.63 Å; distance between nearest atoms, 1.218 Å; d. 5.36. Graphite shows a lattice of the hexagonal close packed type, which is not in agreement with results of Debye. S. K. A. (*C. A.*)

Simplified determination of arsenic. POUSSIGUES. *Ann. chim. anal. chim. appl.*, **5,** 263–7(1923).—The method is similar in principal to that recommended by Copaux for the detn. of H_3PO_4. If a soln. of Na_2MoO_4 in dil. HNO_3 is mixed with pure ether and then treated with H_3AsO_4, 3 layers of liquid result. The bottom layer consists of

an oily, yellowish liquid contg. As and Mo; the middle layer is an aq. soln. contg. the excess of Na_2MoO_4 and the top layer consists of the excess ether. If the reaction takes place in a centrifuge tube graduated at the bottom, which is narrower than the rest of the tube, the quantity of As can be detd. by the depth of yellow liquid. It is necessary, however, to apply a correction for the soly. of the As compd. in the other 2 liquids. By this method of analysis good results are easily obtained in the analysis of tetrahedrite, pyrite and similar minerals contg. more than traces of As and no P. In the analysis it is recommended to use 25 cc. of soln. contg. 2.9 to 25 mg. of As, which should be added to a mixt. of 65 cc. Na_2MoO_4 soln. (100 g. MoO_3 suspended in hot water, neutralized with Na_2CO_3, poured into 700 cc. of 6 *N* HNO_3 and diluted to 1 l.) and 85 cc. of ether. W. T. H. (*C. A.*)

Volumetric method for the determination of magnesium. M. Bulli and L. Fernandes. *Ann. chim. applicata*, **12**, 44–5(1923).—The pptn. of $Mg(NH_4)_2Fe(CN)_6$ from solns. contg. Mg^{++} and $Fe(CN)_6^{----}$ in the presence of NH_4 salts is utilized for detg. Mg volumetrically. When cold, pptn. occurs only in concd. solns., but it is complete in hot dil. solns. with excess NH_4 salt and EtOH, though a direct volumetric detn. could not be developed because of the difficulty of reading the end point. Filtration and detn. of the excess $K_4Fe(CN)_6$ with $KMmO_4$ were not successful because of the difficulty of washing the ppt. and the formation of a ppt. of $Mn(NH_4)_2Fe(CN)_6$. *Procedure.* To the Mg soln. add an excess of $K_4Fe(CN)_6$ and of solid NH_4Cl, heat at 100° for 5–10 min., add approx. 0.05 vol. of EtOH and while hot titrate the excess $K_4Fe(CN)_6$ with 0.1 *N* $ZnSO_4$. The end point is reached when a drop of the supernatant liquid is not colored rose by a U salt. A drop of 0.1 *N* $ZnSO_4$ is sufficient in the titration to transform the rose color to a clear green and the point is sharper than that in the titration of Zn by the method of Galetti. Calc. the Mg from the reactions: $MgSO_4 + K_4Fe(CN)_6 + 2NH_4Cl \longrightarrow (NH_4)_2MgFe(CN)_6 + 2KCl + K_2SO_4$; $ZnSO_4 + K_4Fe(CN)_6 + 2NH_4Cl \longrightarrow (NH_4)_2ZnFe(CN)_6 + 2KCl + K_2SO_4$. C. C. D. (*C. A.*)

The practical application of flue gas analysis. C. F. Wade. *Fuel*, **2**, 202–3 (1923).—Of the 3 methods for detg. CO_2, (1) the intermittent "snap" test, (2) analysis of an av. sample over a period and (3) the continuous automatic record, the value of (2) is questioned, since no data are obtained on the cause of a low % CO_2 or as to whether conditions of firing are uniform or variable. (1) is useful in locating the cause of a low % CO_2 indicated by the automatic recorder, for by test holes at successive passes, an air leakage can be located. (3) should be used for detg. the efficiency of combustion, the presence of excess air and the % CO_2 per unit wt. of fuel consumed, rather than the % CO_2 in the waste gases. Flue gas anal., which has been neglected in regenerative processes, reveals serious losses and great variations in the compn. of chimney gases. C. C. D. (*C. A.*)

PATENT

Process for refining tin and antimony. Georges Bonnard. U. S. 1,475,422, Nov. 27. The herein described process of refining tin and antimony which comprises subjecting crude tin to the action of dry chlorine, separating the liquid chlorides thus obtained from the solid and semi-solid materials, adding water to said liquid mixtures to produce a solution of stannic chloride and decompose the chlorides of antimony, arsenic and sulphur, separating out the solution of stannic chloride, and electrolytically obtaining tin from such solution.

General

Technical education in relation to the refractories industry. G. W. Hefford. *Trans. Ceram. Soc.*, **22** [2], 205(1922–23).—There are undoubtedly numbers of first-

rate men in the industry, so far as their experience goes really first-rate, but for lack of suitable scien. training they are unable to translate the results of research into works practice. The function of research work in connection with industry is something more than the provision of foolproof tips; it is to det. principles and constants, which, by men with training, acumen and imagination can be applied in the circumstances of the particular works in which they are interested. An interesting attempt has just been started at Brierley Hill to provide suitable instruction in refracs.; its success will be detd. largely by the amt. of practical support it receives from the indus., and the amt. of practical sympathy the industry extends to the students. H. F. S.

Prepared non-metallics in Canada. S. J. Cook. *Can. Chem. & Met.*, **7** [9], 226–31(1923).—Includes figures of consumption of many ceram. mats. in Canada during 1922, also a few notes on the production of ceram. products. B. M. L.

Dressing crude chalk by modern methods. A. B. Parsons. *Eng. & Min. Jour. Press*, **116** [10], 415–20(1923).—In its whiting dept., the Benjamin Moore Co., at Carteret, N. J., has cut its costs nearly 50% by re-equipping an old plant with modern mach. Crude French chalk is dressed to remove 8% sand and 20% moisture and the product ground to −300 mesh. A flow sheet and pictures and drawings of mach. in the new plant are given in the article. A grab bucket crane for large unloading, modern conveyor mach., Dorr classifiers and a vacuum filter have reduced the labor force from 38 to 9 workmen of the same ability. Much of this equipment is applicable to the dressing of feldspar, kaolin, silica, etc. B. M. L.

Melting in electric furnace. J. L. Cawthon, Jr. *Foundry*, **51** [23], 938(1923).—A description of current practice in the production of synthetic cast iron in both acid and basic elec. fur. Typical charges, when melted down contain about 2.50% C. To secure a carbon content over 2.75% it is necessary to have a clean bath of superheated metal, agitated vigorously. The silicon content is adjusted by the addn. of 50% ferro-silicon, and manganese is added as ferro-manganese. A rapid method of testing the metal before pouring is given, together with a chart for calcg. mixts. M. E. M.

Describes cupola reactions. J. Coll. *Foundry*, **51** [23], 961(1923).—A review of present day theories concerning reactions within a cupola, with some conclusions by the author. M. E. M.

The dusted lung with special reference to the inhalation of silica dust and its relation to pulmonary tuberculosis. B. S. Nicholson. *J. Ind. Hyg.*, **5**, 220–42(1923). E. J. C. (*C. A.*)

The partial decomposition of certain solid substances effected by grinding. John Johnston. *Rec. trav. chim.*, **42**, 850–4(1923).—The process of grinding a solid may be accompanied by certain changes in the compn. of the mat. In particular it may cause a solid substance, which on dissociating yields a gaseous product, to lose some part of this volatile component. From theoretical considerations it appears that this partial loss of volatile component may occur more generally than has hitherto been supposed; and expt. has confirmed this deduction. In many cases the loss will be unappreciable because the dissoc. pressure is too small or the rate of dissoc. too small, or because the substance is not hard and crushes easily. In other cases like the hydrates the loss may be so large as seriously to affect analytical results. E. J. W. (*C. A.*)

Producer gas and gas-producer practice. III. R. V. Wheeler. *Fuel*, **2**, 182–6, 219–21(1923); cf. *C. A.*, **17**, 203, 3088.—Producer construction, grates, solid-bottom, bar-bottom and H_2O-bottom producers, the body of the producer, the charging hopper, the method of providing the blast and the use of superheated blasts are described with diagrams. C. C. D. (*C. A.*)

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BULLETIN

of the

American Ceramic Society

A Monthly Publication Devoted to Proceedings
of the Society, Discussions of Plant Problems, Discussions
of Technical and Scientific Questions and
Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIAL

THE 1924 ANNUAL CONVENTION

The Annual Convention of the American Ceramic Society is an occasion of paper readings but of more importance is it as an occasion for exchanging information on problems of common concern, and for making personal contacts by which coöperation can be had throughout the year in the solving of problems and the obtaining of information. No man has ever with profit lived for and by himself. Mutual dependency on fellow beings has always been and is increasing. We are profiting from things already accomplished and recorded, but the facts being made known today in both fundamental and applied science are so surpassing in amount and in diversity that a year now is as decades past in the revealings of facts essential to economical manufacturing. Collaboration is now far more necessary. The opportunity and time to find the fundamentals, and the capacity to apply them in the devising of ways and means of manufacturing is beyond the possibilities of individuals working alone. These require the collaboration of many. It is in the establishing and maintaining of personal and organized group contacts through which this essential collaboration is possible that conventions have their greatest justification.

The impression is had by some that the larger number of the papers listed on the programs of the convention of this Society are from Univer-

sities, Bureaus and Institutions of research and from those who supply materials and equipment. This is not and has not been the case. For the 1924 Convention 62.4% of the 169 papers and addresses are from the industrial laboratories and factory operators; 8% of these 62% are trade association releases. Only 14.3% of the papers are from Universities and 23.2% from the public and semi-public laboratories.

It is this 62.4% of papers from the industrial workers that reveals the purpose of these annual conventions and the benefits which accrue to the industrialists who attend. It is a logical conclusion that if this holding of conventions for the past 26 years had not profited manufacturers, the number of delegates attending each year would have decreased rather than increased and the percentage of contributions from the factories would not have continued to be in the majority.

If the SOCIETY served in no other wise than as a means of collaborating in the finding and classifying of records of fact findings, and in making application of these to manufacturing it would be worth while. It is and must continue to be more than this. It must be the medium for personal contacts and social relations of men engaged in like pursuits. Our pace in things mechanical is so swift that real effort must be made to keep the human relations apace. We can now "tune in" for a conversation across the ocean. We are today closer to humans on the other side of the world than were the peoples in a given State a few years ago. Canned music or music vibrating direct from strings thousands of miles away are no longer dreams; they are realities for all who will but "tune in." So it is in all human endeavors, industrial as well. We must "tune in," must have the essential equipment and adjustment.

So far there has been no substitute found for the printed record and for the convening together for collaboration as means of securing this essential equipment and adjustment. No one can afford to isolate himself. He must read. He must convene with others.

PAPERS AND DISCUSSIONS

THE PULSICHROMETER

By Francis A. H. Schepers

The discussions on pulsichrome published in this *Journal*[1] were rather brief. The writer has since had occasion to study the advantages of this machine very carefully. Let us first confine ourselves to the laboratory and shipping department of the terra cotta plant. Our first experience was on a rather large job, approximately 1800 tons of terra cotta. A certain amount of samples were run and after the architect's approval was obtained, we immediately set to work. To date we have finished 500 tons of this job and it is gratifying indeed that there was need of reslipping only one piece. The results were 100% perfect as far as the slipping is concerned.

Motor trouble is unknown to us. These machines have run day after day and week after week without the slightest indication of trouble.

Occasionally the men may have to stop for a few minutes to clean their machines, due to some dirt or grit getting in, which, of course, can be entirely overcome by careful screening of the enamels. This "clogging up" can occur with any ordinary slipping machine if the necessary care is not exercised.

Aside from the good results obtained in the slipping room it reduced the cost of manufacture considerably in this department. Where heretofore it required from four to five men to glaze enough terra cotta in two days to fill a fifty-ton kiln, from two to three men can turn out just as much and better work in the same length of time and consequently reduce the cost of labor approximately 50%.

The same saving applies to the glazes, where, with the old method it required about a barrel of glaze to cover from six to eight tons of terra cotta, this same amount is sufficient for about fifteen tons of pulsichrome terra cotta. These are actual usage figures. Quite a few pieces have been examined very thoroughly under the microscope and although the appearance of the glaze is rather thin, the entire surface is well covered.

The work in general is much simpler. We all have tried at some time or other to "imitate" granites with the old method. In most cases it required four men to apply the different colors and what was the result? Generally a loss of time and money and the material produced looked "something like" granite. After careful study and a lot of switching around of the various pieces in the fitting room to secure a fairly good take up in color (thereby depending largely upon the artistic eye of the fitter

[1] E. Clark, "The Use of Pulsichrome from a Manufacturer's Standpoint," *Jour. Amer. Ceram. Soc.*, **5** [11], 826(1922); L. M. Munshaw, "The Pulsichrometer *vs.* An Old Method of Applying Glazes," *ibid.*

boss) we were satisfied it would pass as "granite." This has been a common occurrence in many plants and we all can see the results daily at the buildings.

The laboratory also benefits a great deal with the use of pulsichrome as the amount of colors used is greatly reduced in number. Large batches of enamels and slips are made up and after the correct specific gravity is obtained, all there is required is a little intelligence on the part of the workman who handles the machine.

Another nice feature is the ease with which certain color combinations are reproduced after a certain length of time, especially in a case of "remakes." It is unnecessary to run all over the yard and find an old overpiece of a certain job or perhaps try to find the man who made it years ago and try to duplicate it, trusting to luck that it will look somewhat like the original job. All we need in this case is the correct specific gravity of the colors, plate number and air pressure and the pulsichrometer will do the rest.

Another fact deserves mention. While heretofore quite often objections were raised by the men in the slipping room about the dust "flying" around with the old method of spraying, we have now a machine which eliminates this nuisance entirely.

Finally we come to the artistic value of the pulsichrometer. How tiresome it is to look at those plain white or cream surfaces on the buildings we all know. They may be practical, but the pulsichrometer will combine beauty with this feature.

Some time ago the writer drove by Terra Cotta Avenue in Chicago (sometimes called Midway) and had an opportunity to observe the various color schemes in the buildings. The most wonderful results have been obtained, and many fine examples of pulsichrome are to be seen. Pulsichrome is in its infancy. Beautiful things have been created in the course of a few years and let us ask the question now; what are we going to see in the next ten years? This answer is solely up to the terra cotta manufacturer. We cannot afford to let everybody have his way about it, for if we do pulsichrome will be discarded in a very short time. The success of it lies in the coöperation of the architect with the plant chemist. If the practical chemist, with his broad knowledge of colors and color combinations can foresee freaky results, it is his duty to caution the architect and only put those combinations on the market which are a credit to pulsichrome. The experienced plant chemist holds the future of the pulsichrometer, on his good judgment and artistic feelings depends the production of material of value.

Let us be conservative with the selecting of colors and entrust the machine only to those who are capable of handling it. We can put a box of paint and brushes into the hands of a child, but will this child produce

anything of value? The same with the pulsichrometer. The people will have to be shown what can be produced by the intelligent selection of colors, the experienced man must in his turn instruct the novice to use only such colors that will give perfect harmony and express the beauty of terra cotta.

Pulsichrome is also an important factor in combination with polychrome. We are well aware of the deplorable results that can be seen in polychrome. Pulsichrome eliminates this completely. Once a certain combination of colors is decided upon, each one of these colors can be used separately for decorating certain fields and the result is that pulsichrome combined with polychrome is in harmony, it is bound to produce a pleasing effect, something soothing to the eye without having to wear smoked glasses in order to be able to stand the strain in looking at them.

The pulsichrometer is a source of untold mysteries. Sometimes we are trying to get a certain color effect, and how agreeably are we surprised when our experimental work comes from the kilns, and we say to ourselves that we do not remember putting that certain color combination on the samples. How many times do we produce an effect, that we were not looking for at all, something better and more beautiful than we expected? The old method of glazing did not possess the charm and power to blend the different oxides to produce color schemes hitherto unknown.

We have gone a great step forward in making good our statement, that "terra cotta shall look like terra cotta" and not be an imitation of some other material. Pulsichrome has its unique appearance and wherever it is used on a building will immediately characterize the material as the "nec plus ultra" of terra cotta.

The Advance Terra Cotta Co
Chicago Heights, Ill.

ELIMINATION OF WASTE IN THE HEAVY CLAY PRODUCTS INDUSTRY

By Marion W. Blair

Waste in various forms is characteristic of American methods in general. We were horrified by our own reckless extravagance in waging the late war, but we continue year after year to pay an increasing bill of upward of $25,000 per hour for preventable fire loss. We let $30,000 per hour run to waste at Niagara Falls, and continue to pay an annual board bill for rats amounting to more than $200,000,000.

These figures throw into insignificance the petty waste of coal, oil, time and labor existing in the manufacture of heavy clay products. There is this outstanding difference, however. The fire and rat loss is borne collectively by 110,000,000 people, and it is difficult to place individual

responsibility, but the waste sustained by the manufacturer of heavy clay products is borne by the individual responsible for it, or by his close business associates and financial backers.

The waste begins with the establishment of the plant, purchase of its site and raw material supply. Hundreds of acres of needless shale and clay lands or mineral rights are bought, and future years must carry the burden of sleeping capital and extra taxation.

Land that is barren and worthless suddenly takes on a new value as raw material when acquired by a clay working corporation.

One million brick per foot acre of clay is a conservative figure. There is then a possible 25,000,000 or 50,000 per day for two years in an acre of clay 25 feet deep, with 50 years operation in a 25-acre deposit of clay 25 feet deep. It would seem a needless waste of capital to tie it up in land which probably will not be touched for 200 years. Capital at 6% unemployed eats its head off six times in a century.

Complete monopoly of raw material in any given district is an impossible if not an undesirable condition. The inability to make future purchase at a relatively reasonable figure is an unlikely condition, and has not been borne out by past experience. However, cumbersome and useless property with a fictitious value has been an obstacle to the sale of many plants, and has been an important factor in the failure of clayworking enterprises.

Plants have been built to supply a temporary local demand without any chance of marketing a future output at a profit, and the growing necessity of entering new fields develops the fact that the relation of market and location had been entirely overlooked. The waste due to poor location eats into profits year after year, and no amount of ingenuity can make it up. Building without competent engineering service often prolongs the period of eye tooth cutting characteristic of the first year's operation of most new plants—and a standardized product is much slower to attain.

The majority of the going plants, the exception being a dozen or so recently built and properly engineered, are suffering from these handicaps of bad judgment and misapplied capital.

Other wastes, those of operation, due largely to lack of attention to small details, can be very greatly reduced or eliminated, and therein lies a profit not to be despised in spite of higher fuel and labor and almost prohibitive freight rates.

Those plants which have been established some years are suffering wastes as a matter of habit. Things are done thus for no other reason than that they have been done thus in the past. If a question is raised the answer is that so and so is a practical man and has been doing it that way for twenty-five years. But suppose it can be done better or cheaper or both, does twenty-five years of past error or ignorance justify twenty minutes continuation if it is losing money? No matter how much profit there

may be in a particular operation, money is being lost if it is possible to do it cheaper and better. For instance, long time burning has been shown to be unnecessary on plant after plant. The operation has been guessed at for years by the so-called practical man. Pyrometer systems have been fought by him—in some cases thrown in the discard as useless—and the eight and nine day burn continues, involving a waste of time, labor, fuel and capital. Many burns are carried along eight or nine days because of fear of carbon and consequent swelling, and the burner would prefer, through indifference or ignorance, to shovel coal two days rather than arrange proper trials to be drawn to determine when the carbon has disappeared and it is safe to raise the heat.

It is perhaps typical of the industry that some $20,000 has been spent in the last two years to convince itself that time and fuel can be saved on present equipment by knowing at all times how hot the kiln is, and keeping the fires going so as to advance the heat continuously. Yet more than ten years ago six day burns of shale paving block in periodic kilns were not unknown, but an intelligent application of the discovery to the industry has not yet been made. It was thought better to burn 25% excess fuel and play safe than to risk even one kiln in an effort to save that amount.

I once read a story of a business man who walked over a fairly prosperous farm and threw down in cash the value of machinery which was lying about ruined by exposure to weather and careless abuse. Twenty dollars here for a plow, two hundred for a binder, a dollar for a spading fork, to say nothing of scythes hung in trees and crops left to rot on the ground. I have often thought that a reckless banker could find a good day's amusement on the average brick plant sowing silver in the place of half- or never-used equipment—bolts, railroad spikes, wheelbarrows, clay cars, locomotives, pugmills, cutting tables, brick machines, engines, and boilers lying about—the management either too sentimental or worse to turn same into cash either as second hand equipment or scrap.

Covering for steam pipe pays for itself in forty-five days. The job should be complete and include fittings, valves and separators. The plants whose steam lines are not covered are paying for the material eight times a year, and getting nothing for the money.

Engine oil which should go through a thirty-five dollar filter and be reclaimed goes into the ground around the foundation.

Driers are crowded and each attempt to set green ware results in excessive waste, both in bats on the drier cars and number two ware in the kilns. Burned bats are carted to the dump rather than repair a kiln floor. Number 1 brick go out with the No. 2 and No. 2 with the No. 1. Weights are not checked—a die is run as long as it will produce a column. If oversize it wastes material, power, fuel and freight. A small amount per brick runs into hundreds of dollars on a ten million production.

Kilns are allowed to cool according to the weather and seldom on a schedule; the invested capital and production they represent idle and limited.

Repairs are ordered after a breakdown. Not in advance.

One plant in a thousand owns or uses indicators, anemometers, gas analysis outfits or other controlling apparatus. Such operations as could be accurately measured are guessed at, and the result is waste—boiler walls and arches leak, air heat of exhaust steam goes through the roof instead of into feed water.

There are plants where the test for a hot drier is to spit on the fan housing, and kiln fires regulated by kicking a gas valve. Is it any wonder that the past year has seen plant after plant shut down for lack of business at a profitable price, or that there has been almost a square yard of concrete pavement laid for each brick that has been so used?

Criticism without constructive suggestion is worthless, and the natural question after such an arraignment as the foregoing is, "What is the solution?" The answer has not changed a particle in two years, and it will not change in another fifty. It is the employment of trained minds in responsible positions—foremanships and superintendents—men who have been taught to think from cause to effect and back again. The payment of sufficient salaries, and enough of them to hold the technical men in the industry and keep them out of white collars.

ST. LOUIS, MO.

DISCUSSION ON "SUBSTITUTING OIL FOR PRODUCER GAS"[1]

G. Ross:[2] We are using Mexican fuel oil of 12–13° Baumé, preheated at about 45°C in burners, to heat a furnace of 7 x 1.3 m. section. The depth of this furnace is 2 m. For our purposes the highest regularity and highest division possible of the developed calories is of the biggest importance. To spread the flames and calories regularly on the surface of 7 x 1.3 m. we made many trials with pressure, temperature and gravity of oil.

The temperature we need is about 1450°C. First we began with oil of 16°Bé. But soon we remarked a partial decomposition of the atomized oil, the fumes charged with oil gases brought them to the lower parts of the furnace till to the top of the chimney of 25 m. high.

At the high temperature we need a heavier oil to avoid decomposition, which burns slower and makes it easier to divide the calories throughout the furnace section. The 12°Bé gave us satisfaction. Essaying the pressure for the purpose of spreading the flames as regularly as possible and to arrive at the same time at the highest temperature to be developed

[1] *Bull. Amer. Ceram. Soc.*, **2** [12], 373 (1923).

[2] Metallurgical Engineer. Saltillo, Coah., Mexico.

near the mouth of the burner, we first used 40 pounds. But these pressures gave us the bigger part of the calories $^2/_3$ of the way from burner to the end of the furnace. The combustion of the mixture of oil and air was too late to permit us to arrive at the highest temperature we need. With 10–12 pounds the result was the best for assuring high temperature at about 1 m. distance from the burner and to bring the calories about everywhere in the section.

To bring the calories necessary to the objects placed in the laboratory of the furnace, we are burning with a slight excess of atomized oil. In this way the calories are transmitted the best to the objects to be handled, the carbon particles of the excess fuel oil are necessary for heat transporting and transmission.

The price of Mexican fuel oil we use is about 0.60–0.65 cts. per barrel in the car at Tampico. The ton of oil cif workplant is about 10 dollars. Mexican coal will be about 7 dollars cif. Costs for our purposes are cheaper with oil than with the coal.

ACTIVITIES OF THE SOCIETY

THE ROSTER IS RISING

Thirty-three persons and six corporations joined during the month of December 15 to January 15. A good start is already had for a big record for January. The "saturation point" is not yet in evidence. Who said this could not be a SOCIETY of 3000 persons and 500 corporations? It can and it will as long as each member does his share of coöperating. The net totals to date are 1990 persons and 296 corporations or a grand total of 2286.

The record for the year 1923 by months is as follows:

	Persons	Corporations			
January	110	10	August	17	3
February	29	0	September	15	2
March	37	3	October	68	30
April	37	7	November	29	6
May	32	7	December	31	6
June	20	6			
July	27	5	Total	452	85

The net gains by years have been as follows:

1918	180	33	1921	221	47
1919	231	44	1922	261	77
1920	181	15	1923	379	80
			Total	1453	296

Is there any evidence here of a let-up in the rapid roster rise? Is the SOCIETY nearing the "saturation point?" No.

NEW MEMBERS RECEIVED FROM DECEMBER 15 TO JANUARY 15

PERSONAL

H. Clinton Baldwin, Y. M. C. A., Perth Amboy, N. J., Roessler & Hasslacher Co.

Harold D. Barger, Salesman, Wellsville Fire Brick Co., Wellsville, Mo.

R. F. Benzinger, The Electric Furnace Co., Salem, Ohio, Vice-President and Sales Manager.

H. R. Borland, 206 Barker Ave., Peoria, Ill., Ceramic Engineer, Peoria Brick & Tile Co.

Emil Bronlund, Brule Mines P. O., Alberta, Canada, Superintendent, Blue Diamond Coal Co., Ltd.

William T. Christian, Supt., Wellsville Fire Brick Co., Wellsville, Mo.

Robert L. Clark, 3101 Passyunk Ave., Lab. Asst., U. G. I. Contracting Co., Philadelphia, Pa.

Anthony Di Dio, Glenn Hotel, Richmond, Calif., Chemist, Pacific Sanitary Mfg. Co., Vitreous Plant.

Morgan B. Eilert, Red Bank, N. J., Supt., The C. Pardee Works, Perth Amboy, N. J.

Chas. F. Eilert, Red Bank, N. J., Manager-Secretary, The C. Pardee Works, Perth Amboy, N. J.

Roger L. Fellows, 109 N. Ashland Ave., La Grange, Ill., University of Illinois.
Shinzaburo Fuzita, % Mitsui Dyestuff & Chemical Works, Omuta, Japan, Engineer of the Fire Brick Department.
Robert Galbraith, Crystal Lake, Ill., Lab. Asst., American Terra Cotta & Ceramic Co.
Gustave Glocker, North East Porcelain Co., North East, Md.
E. Carlile Gravatt, 59 N. Pearl St., Bridgeton, N. J., Illinois Glass Co.
Earl B. Hagar, Asst. Supt., Wellsville Fire Brick Co., Wellsville, Mo.
W. D. Harvey, Monarch Engineering Mfg. Co., 1206 American Bldg., Baltimore, Md.
Earl L. Hauman, Hillview Place, Hamburg, N. Y., Engineer, Electro-Refractories Corp., Buffalo, N. Y.
Raymond A. Heindl, 4917 43rd St., N. W., Washington, D. C., Asst. Chemical Engineer, Ceramic Division, U. S. Bureau of Standards.
C. Walter Kelly, Jr., 3756 Hancock Ave., W., Detroit, Mich., Sales Manager, Face & Fire Brick Division, United Fuel & Supply Co.
Edward R. Ketchem, 242 North E St., Hamilton, Ohio, Enameling Plant, Estate Stove Co.
H. G. Kiger, Manager, Wellsville Fire Brick Co., Wellsville, Mo.
William C. Loudon, 2635 Norman Ave., Detroit, Mich., Head Mason Inspector, Detroit City Gas Co.
Leroy Marx, % The Denver Terra Cotta Co., Box 1860, Denver, Colo., Ceramist.
Daniel J. McSwiney, 1819 Maple St., Alton, Ill., Consulting Chemist.
George Z. McClelland, Gladding-McBean & Co., Lincoln, Calif.
Harold V. E. M. Renn, Sowerby's Ellison Glass Works, Glass Technologist, Gateshead-on-Tyne, England.
William Reynolds, Asst. Supt., Scranton Enameling Co., Scranton, Pa.
Murray Sinclair, West Morris St., Bath, N. Y., H. P. Sinclair & Co.
George Sirovy, 1486 Perry St., Des Plaines, Ill., Enameler.
Evelyn Tennyson, Alfred University, Alfred, N. Y. (Student Member).

CORPORATION

Buckwalter Stove Co., Royersford, Pa., Joseph A. Buckwalter, Treasurer.
Cleveland Metal Products Co., Cleveland, Ohio, C. A. Blackburn, Superintendent.
Grand Rapids Refrigerator Co., Grand Rapids, Mich., Charles H. Leonard, President.
Mansfield Vitreous Enameling Co., Mansfield, Ohio, P. A. Adams.
Scranton Enameling Co., New York & Jefferson Aves., Scranton, Pa.
Wolverine Porcelain Enameling Co., 3350 Scotten Ave., Detroit, Mich.

PERSONAL NOTES OF MEMBERS

A. R. Anderson of the Kentucky-American Clay Co., requests that his address be changed to Pineville, Ky.

Robert E. Armstrong, salesman for Harbison-Walker Refractories Co., has moved to 712 E. 50th St., Indianapolis, Ind.

Edwin P. Arthur, formerly of Columbus, Ohio, is at Morgantown, W. Va., 701 Willey St.

Edgar Boblett, formerly of Nappanee, Ind., is located at Culver, Ind.

B. M. Burchfiel has completed his work with the Los Angeles Pressed Brick Co., and is now connected with the Pacific Clay Products Co., Inc., 306 West Avenue 26, Los Angeles, Calif.

H. T. Bush is at Inglebush, Porte Hope, Ontario, Canada.

Rod. Castro Oliveira gives as his permanent address Casilla 4049 Santiago, Chili, S. A.

Max D. Compton is now living at 4254 Moneta Ave., Los Angeles, Calif.

Karl Ford, of the Bureau of Standards, Washington, D. C., has moved from Silver Springs, Md., to 1333 30th St., N. W., Washington, D. C.

Major E. Gates, who has been located at 138 N. LaSalle St., Chicago, Ill., has moved his office to 128 N. Wells St.

Clarence A. Hall, has moved from Cresheim Arms, Allen Lane, Mt. Airy, to 7951 Winston Road, Chestnut Hill, Philadelphia, Pa.

Mitsu Kato, who has been listed among "Unknown Addresses," gives Mitsuishi-cho, Okayamaken, Japan, as his address.

Walter T. Lippert gives as a new address 123 Fayette St., Bridgeton, N. J.

Crawford Madeira has moved from 900 North American Bldg., to the Atlantic Bldg., Philadelphia, Pa.

Jefferson Middleton gives as his address 3401 16th St., N. W., Apt. 23, Washington, D. C.

Frank E. Owen, formerly of Findlay, Ohio, is now with the General Porcelain Co., Parkersburg, W. Va.

F. W. Owens requests that his mail be sent to the National Enameling & Stamping Co., 1901 Light St., Baltimore, Md.

George W. Parker is located at 603 Laclede Gas Bldg., St. Louis, Mo.

R. J. Riley has notified the Secretary's office that he has moved from Brightwood, Ind., to Terra Cotta, Ill.

T. D. Tefft is now located at Darlington, Pa.

Erwin F. Theobald requests that communications be sent to him at 1413 13th St., N. W., Canton, Ohio.

Boris Trifonoff has moved from Muncie, Ind., to 1210 Elm St., Zanesville, Ohio.

Ray T. Watkins is now living at 503 S. Race St., Urbana, Ill.

Robert C. Zehm, formerly with the Bureau of Mines, is now employed with the Los Angeles Pressed Brick Co., Los Angeles, Calif.

MEMBERSHIP WORKERS' RECORD

	Personal		Personal	Corporation
Charles F. Binns	1	Percival Marson	1	
B. F. Carter	1	L. M. Munshaw	1	
R. R. Danielson	1	Andrew N. Outzen	1	
Geo. P. Fackt	1	Carl Perg	1	
R. F. Geller	1	W. A. Potter	1	
V. A. Giesey	1	Hachiro Saito	1	
Roland J. Gouin	1	George Simcoe	1	
R. K. Hursh	1	Donald E. Sharp	1	
I. A. Krusen	4	Karl Turk	1	4
Paul G. Larkin	1	Otto W. Will	1	
Walter T. Lippert	1	Office	6	2
M. E. Manson	1		—	—
		Total	31	6

ADDRESSES UNKNOWN

Members of the AMERICAN CERAMIC SOCIETY are urgently requested to forward the correct addresses of the following persons whose *Journals* have been returned to the office of the Secretary as a result of an insufficient or incorrect address. The address given below with the name is the last one which appeared on the official file of the SOCIETY.

Fred J. A. Arbenz, Florentine Pottery Co., Cambridge, Ohio.
G. L. Austin, Joliet, Ill.
G. V. Baker, Penn Feldspar Co., Barnard, N. Y.
Earl A. Bickel, Postville Clay Products Co., Postville, Iowa.
Fred H. Butterfield, 4906 McPherson Ave., St. Louis, Mo., Crunden Martin Mfg. Co.
A. Marietta Byrnes, 63 Anderson Place, New Orleans, La.
J. P. Callaghan, % Teaque Hotel, Montgomery, Ala.
C. V. Cameron, Whiting-Mead Commercial Co., 2035 E. Vernon Ave., Los Angeles, Calif.
Homer T. Darlington, Box 736, Natrona, Pa.
S. E. Davis, 1117 Murdock Ave., Parkersburg, W. Va.
Charles S. Dolley, Keramoid Mfg. Co., Fort Madison, Iowa.
L. E. Ells, 4255a Flad Ave., St. Louis, Mo., Laclede-Christy Clay Products Co.
Koji Fujioka, Shofu Porcelain Mfg. Co., Kyoto, Japan.
M. S. Gifford, Lake Bluff, Ill.
William Gardner, Gardner Feldspar Co., Hartington, Ontario, Canada.
A. H. Goodman, Box 915, Pittsburgh, Pa.
George M. Grady, 74 Pacemont Rd., Columbus, Ohio.
John L. Greenwood, Lehigh Sewer Pipe & Tile Co., Lehigh, Iowa.
Park Hitchins, 1447 Oliver Bldg., Pittsburgh, Pa.
Sidney H. Ivery, 4432 Gibson Ave., St. Louis, Mo.
William J. Johnson, 4148 Langland St., Cincinnati, Ohio.
Y. Kitamura, Shofu Kogo Kafushiki Kaisha, Kyoto, Japan.
E. W. Koering, Crystal Ave., Vineland, N. J.
Charles E. Kraus, 110 W. 40th St., New York, N. Y.
George J. Lawrence, J. B. Ford Co., Wyandotte, Mich.
Arthur T. Leahy, 5490 Ellis Ave., Chicago, Ill.
William H. Marr, % Canadian Libbey-Owens Sheet Glass Co., Hamilton, Ont., Canada.
J. J. Miller, % Nesbit & Bollen, 403 Liberty Ave., Pittsburgh, Pa.
Leon W. Mitchell, Rock Island, Ill., Rock Island Stove Co.
W. O. Mitscherling, % Atlas Powder Co., Wilmington, Del.
Knud Y. Chr. Moller, 4956 McPherson Ave., St. Louis, Mo.
F. H. Nies, Cor. Hamilton Ave. & Summit St., Brooklyn, N. Y.
K. Okura, 84 Kobayashi-Cho, Nagoya, Japan.
J. Clair Peck, 4961 Neosho St., St. Louis, Mo.
W. Pendrup, Coonley Mfg. Co., Cicero, Ill.
Frank J. Pohs, 1097 Interstate Ave., Portland, Ore.
E. K. Proodian, Newtown, Bucks Co., Pa.
H. M. Pulsifer, Manhattan Bldg., Chicago, Ill.
Paul Q. Quay, Lake Shore Blvd., Euclid, Ohio.
G. W. Rathjens, 6100 Dorchester Ave., Chicago, Ill.
W. H. Reid, 10 Stanley Pl., Yonkers, N. Y.
Cedric L. Rennieburgh, A. C. Spark Plug Co., Flint, Mich.
J. E. Thompson, 2507 Townsend Ave., Detroit, Mich.

John F. R. Villalta, Apartado No. 65, Barcelona, Spain.
William J. Vodick, 1733 Lake Ave., Wilmette, Ill., Chicago Hardware Foundry Co.
Frank A. Weidman, 38 S. Dearborn St., Chicago, Ill., Inland Steel Co.
E. J. Winkleman, Box 1122, Pittsburgh, Pa.
Miles M. Zoller, 208 S. LaSalle St., Chicago, Ill.

PITTSBURGH SECTION MEETING

The annual business meeting and election of officers for the Pittsburgh Local Section of the SOCIETY was announced for the evening of January 22, 1924. Following a dinner served at the University of Pittsburgh Cafeteria, the meeting was to take place at Mellon Institute. A four-reel motion picture, "The Story of Refractories," was to be shown prepared by the U. S. Bureau of Mines and Laclede-Christy Company.[1]

DETROIT SECTION MEETING[1]

The Time: January 22nd Dinner at 6:30 P.M.
Lecture at 8:00 P.M.
The Place: Elk's Club
The Speaker: A. V. Bleininger (internationally known authority on refractories).
The Subject: "The Properties of Refractories from a Physical and Chemical Standpoint."

This talk will be presented in a clear concise form which anyone can understand, and will follow up Mr. Bleininger's first talk on "Specifications for Refractories." This will be followed later by a third talk entitled, "Specifications for Refractories Used in the Metallurgical Industries." At a fourth meeting a five-reel motion picture showing in detail the manufacture and applications of refractories to the industries will be presented.

CHICAGO LOCAL SECTION

Election of officers of the Chicago Section of the AMERICAN CERAMIC SOCIETY was held in Chicago, December 15, 1923, at the Morrison Hotel. The officers for the new year are:

President: H. C. Beasley, Supt., Coonley Mfg. Co., Chicago.
Vice-President: William Knowles, Titanium Alloys Co., Chicago.
Secretary-Treasurer: R. A. Rahn, Leveltown Potteries, Chicago.
Councilor: C. W. Parmelee, Ceramics Dept., University of Illinois.

Papers were read by L. H. Menne and W. A. Hull.

WANTED: AN ANALYTICAL SECTION

BY H. H. STEPHENSON

On coming to this country one received many impressions of which the first was pleasure at the high quality of the ware produced, and the second a mild surprise at the scarcity of works laboratories and the very moderate salaries paid to chemists.

[1] Received in Secretary's office, January 15, 1924.

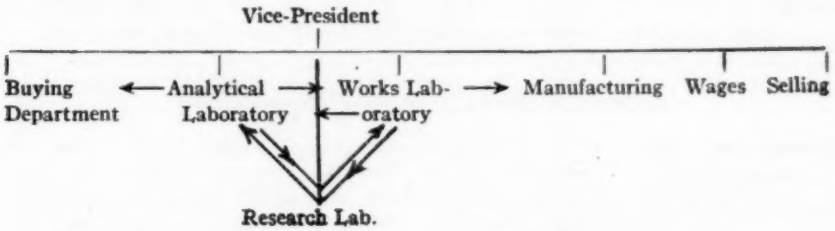
The legend in Europe is that American research has infinite financial resources behind it.

It is of my third and fourth impressions that I wish to speak, and these concern (*a*) purchase of raw materials, (*b*) loss in manufacture.

The answer to both lies in the analytical laboratory.

Raw Materials.—The very first analysis I did in this country of an important, ingredient delivered in bulk at a plant showed that the material was hopelessly inferior, and we obtained a letter of "explanation" from the sellers. In England there would have been a law case with some hundred dollars for a few minutes chemical evidence on the stand. But nothing happened. The manufacturer seemed to think it natural to pay a good price for a 40% adulterated article.

The following scheme shows the rightful position of the chemists:—



The purchase of a raw material should be conducted on rigid lines: Vice-President initials list of sellers. Buying department asks for quotations and samples. Chemist analyzes them and reports on the purity, on the presence of harmful impurities, and on the price calculated to 100% purity. Vice-President decides, and a specification is made out to govern the bulk delivery according to sample. Immediately the consignment has reached the plant, and before the sale is completed, the chemist makes a representative sample and analyzes it. If not up to the original, the consignment is returned at seller's expense.

I take "yellow oxide" of uranium (sodium uranate), though any example on a large scale would do as well.

Sample A at $3 a pound, Sample B at $4, Sample C at $5.

A contains 45.27% $Na_2U_2O_7$
B contains 70.84%
C contains 93.96%

The remainder in all cases being sodium carbonate with less than one per cent of non-harmful impurities.

At 100% $Na_2U_2O_7$, A costs $6.62, B costs $5.64, and C $5.32 is cheapest and is ordered. Bulk deliveries were 90.22 and 90.92% $Na_2U_2O_7$. C is satisfactory.

This is the only method by which a manufacturer can get 100% efficiency in his purchasing department, and it excludes graft. The reader is doubtless aware that in England there is a law against an employee of one firm taking a commission from another firm. A conviction under that law would hardly be possible without the assistance of the analytical chemists.

Loss in manufacture in this country is certainly twice the loss in European plants, though most firms are in the happy position of being able to ignore it. I have heard it said that the American workman, unlike the American middle class and unlike any class in the old country, puts his wages before his work, but even if that were true it would not be true when a family heritage of the potter's craft has had time to get es-

tablished. Nor can it be attributed to methods of burning. The American kiln is as efficient as the European.

Thus we come back to the variation of raw materials. A hundred ton lot of feldspar should have exactly the same composition in every bag and in every part of every bag.

The facts are, therefore, that an analytical laboratory can halve the loss in manufacture, and take anything from ten to 40% off the cost of raw materials. What is on the debit side? The equipment of a laboratory, $500, and the salary of a chemist, $3000.

An analytical section is wanted to put this across to the manufacturers, to standardize the construction of ceramic laboratories, to coördinate the activities of committees and societies on specifications, and to strengthen the legitimate position of the analytical chemist.

SUMMER MEETING OF THE SOCIETY

Interesting trip to Pacific Coast, July 21–Aug. 16

Following out their plan of "seeing America First" the members of the AMERICAN CERAMIC SOCIETY will leave Chicago on the evening of July 21, 1924 for a four weeks' trip to the Pacific Coast. From Spokane, Wash. and Puget Sound on the north to the southern part of California, members will have the opportunity of seeing both the development and enthusiasm of the western ceramic industries and also one of the most beautiful sections of the country. A more satisfying trip for the SOCIETY has never been given and never before have the plans been laid so carefully and matured so early as for this inviting trip.

With Chicago as the central starting point, members will gather from the eastern and central states and leave on a private train for Spokane, Washington.[1] The committees of the Pacific Northwest, San Francisco and Los Angeles are already announced and have completed many plans for the comfort and entertainment of the visitors.

In Washington stopovers and visits will be made at Spokane, Freeman, Mica, and Seattle and Auburn. Sight-seeing trips will be made to Mt. Rainier and on Puget Sound. California stopovers will include, Lincoln, San Francisco, Merced, El Portal, Yosemite Valley and Los Angeles and vicinity.

The return trip will be made by any of the transcontinental routes selected by the members and no effort will be made to return to Chicago as a party. A stopover may be made at Grand Canyon if desired.

Summer tourist rates have been secured making the approximate railroad fare including side trips $200.00. This does not include food or hotel expenses.

Early reservations must be made to the Secretary's office, Lord Hall, O. S. U., Columbus, Ohio. These must be in the office on or before June 1.

The Local Committees announced for the western states are as follows:

F. B. Ortman, Tropico Potteries, Glendale, Cal., *General Chairman.*

Pacific Northwest: Hewitt Wilson, University of Washington; Samuel Geijsbeek, Geijsbeek Engineering Co., Seattle, Wash.; Paul S. Mac Michael, Northern Clay Co., Auburn, Wash. (Members to be named.)

Los Angeles: Findlay Drummond, Alberhill Coal and Clay Company, *Chairman.* (Members to be named.)

[1] A private train will be secured if 125 members sign up for the trip. Otherwise private coaches will be secured.

San Francisco: A. L. Gladding, Gladding, McBean and Co., *Chairman;* J. T. Roberts, Stockton Fire Brick Company; N. A. Dickey, Livermore Fire Brick Company; Otto Rosenstein or Kenneth M. Henry, Illinois-Pacific Glass Company; W. Newton Stearns or W. A. Potter, Pacific Porcelain Ware Company.

OBITUARIES

Lemon Parker

Lemon Parker, 67 years old, president of the Parker-Russell Mining and Manufacturing Co., 3314 Morganford road, died of heart disease today at his home, 3413 Oak Hill Avenue, St. Louis, Mo. He had been ill two years and had not been active in business for some time.

Mr. Parker was an active member of the SOCIETY since 1904, and an ever loyal supporter of the SOCIETY. He will be remembered as the originator of the load test at high temperatures. His early experiments are described in Volume 7, p. 185 of the *Transactions* of this SOCIETY published in 1904.

Oscar B. Scherer

Word has been received of the recent death of Oscar B. Scherer, of 5 N. Karlov Ave., Chicago, Ill. Mr. Scherer has been a member of this SOCIETY for a number of years and was known among the enamel manufacturers.

NOTES AND NEWS

MEETINGS OF POTTERY SUPERINTENDENTS AND FOREMEN IN EAST LIVERPOOL, OHIO

There have been held two meetings of the newly formed association of pottery executives. The first meeting has already been reported.[1] The second one held, December 14th, in the rooms of the Potters' Association was a still more pronounced success, there being present about 80 men. At this meeting a number of the working rules governing the relation between the manufacturers and the operative potters were discussed in detail. The desire was expressed that more uniform practices be adopted in dealing with the men. Several problems submitted in the question box which has been made a feature of all programs were given lengthy consideration. With the development of the field of activity of this organization it is certain that future meetings will be crowded with pressing questions. One of the most desirable and pleasing features is the opportunity thus afforded the men from the different plants to become acquainted in the pleasant surroundings of the club. Through the courtesy of the U. S. Bureau of Mines a film was shown which gave the story of refractories as illustrated by the operations of the Laclede-Christy Clay Products Co.

WORK OF THE RESEARCH COMMITTEE OF THE U. S. POTTERS' ASSOCIATION

During the past year the Association has maintained a fellow at the Bureau of Standards, Washington, D. C., who has nearly completed his work. The investigation deals with the study of facts relating to crazing, with particular reference to the thermal

[1] *Bull. Amer. Ceram. Soc.*, **2** [12], 397 (1923).

expansion of the body and glazes, the effect of heat treatment, thickness of the glaze, mechanical strength of body and glaze and effect of the firing upon the microstructure of the body. Already some facts have been accumulated which show that the usual conceptions as to the relation between body and glaze are in error. The work will be completed as soon as possible which should be within the next two months and reported to the Association.

Besides this work the committee has reported upon several subjects, such as sagger preparation, refractories, crazing and the strength of sagger mixes in the dried and fired state. At the present time the activities of the organization are confined to the research mentioned above, at the Bureau of Standards, the study of the sagger question and an investigation of the Texas kaolin. The last-named topic has come up for consideration because of the report that large deposits of this material are actually available at the present time, reports which seem to be substantiated. It is expected that twelve potteries will take part in the work of testing out the Texas clay in a practical way.

CLAY PRODUCTS COURSE ADDED AT STATE COLLEGE

For the first time in Pennsylvania history, young men of the state desiring to make the clay working industries their life profession, will now be able to secure a higher education in ceramic engineering without finding it necessary to go to another state. President John M. Thomas today announced the appointment of J. B. Shaw as head of the newly created department of ceramic engineering at the Pennsylvania State College.

Pennsylvania stands second of all states in the value of its yearly output of clay products, including brick, tile, terra cotta and fine clay pottery, totaling over $31,000,000.

J. B. Shaw

There are almost 1000 separate clay working industries in the state employing over 12,000 wage earners. Ceramic engineers have been drawn by these industries from colleges in New Jersey, New York and Ohio, but within the next few weeks young Pennsylvanians anxious to train for this important field will be able to enroll as ceramic students in a four year training course in the Penn State School of Mines, where the second semester starts on January 28.

For many years State College has had demands for ceramic engineers. The new department was authorized by trustees several months ago, and after a long search Professor Shaw was secured as the proper man to take charge. He has been professor of ceramics at the New York State College of Ceramics, at Alfred, N. Y., for eight years. He was graduated as a clay products, or ceramic engineer, at Ohio State University, and has had fifteen years of experience in that field.

The location of this course at State College is fortunate, for throughout central Pennsylvania there is a wide diversity of clay, glass sand, ganister and other plants within easy reach of the college. The college maintains a well equipped laboratory, and the teaching of the subject in the mining school with its geology department is another special advantage.

REPRINTS FROM ANNUAL TABLES

The Secretary-General of Annual Tables announces that the following list of reprints from Volume IV is available for sale at the prices indicated.

	Pages	Price (Fr. francs) Paper	Bound
"Spectroscopy," by M. L. Brüninghaus. Preface by A. Fowler, F. R. S.	210	35	45
"Electricity, Magnetism, Conductivity of Electrolytes, Electromotive Forces," by MM. Malapert, v. Weisse, R. E. Slade and G. L. Higgen. Preface by F. B. Jewett	144	30	40
"Radioactivity, Electronics, Ionization of Gases," etc. by MM. J. Saphores and F. Bourion. Preface by by Sir E. Rutherford, F. R. S.	19	10	18
"Crystallography and Mineralogy," by L. J. Spencer. Preface by Sir Henry A. Miers, F. R. S.	65	15	25
"Biology," by E. Terroine and H. Colin. Preface by Jacques Loeb	37	12	20
"Engineering and Metallurgy," by L. Descroix. Preface by G. K. Burgess	154	30	40
"Colloids," by E. Rebière. Preface by Jacques Duclaux	9	6	12

These reprints contain all of the data for the subjects indicated which are found in Volume IV of Annual Tables, which volume covers the literature of the world for the years 1913 to 1916, inclusive. Specialists having occasion to refer frequently to data in the fields covered by any of these reprints will find them invaluable for ready reference, and at the present rate of exchange the cost of these reprints is very small.

Members of any of the organizations listed below are entitled to a 50% discount on the prices given above.

Orders for any of these reprints should be sent direct to Dr. Charles Marie, 9 Rue de Bagneux, Paris 6, and should be accompanied by an international money order or a draft on Paris covering the price of the reprint plus two francs for postage and packing on each order.

National Academy of Sciences
Philosophical Society of Washington
American Philosophical Society
American Academy of Arts and Sciences
American Association for the Advancement of Science
American Institute of Chemical Engineers
American Institute of Electrical Engineers
American Electrochemical Society
American Chemical Society
American Ceramic Society
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing Materials
American Institute of Mining and Metallurgical Engineers

EXPERIMENTAL DATA LOST

Shinzo Satoh, of the Toyko Electric Company, Kawasaki, Japan and a member of this SOCIETY has written to friends of his loss in the recent earthquake. Mr. Satoh narrowly escaped death when his laboratory collapsed and he was badly injured. All of the data which he had gathered through several years of experiments and studies were lost.

PROPOSED INVESTIGATIONS IN HEAT TRANSMISSION

Division of Engineering, National Research Council: Objects

1. To provide designing, operating, and research engineers with reliable information on heat transmission in as simple and convenient shape as is compatible with accuracy.

2. To analyze theoretical and experimental data already published or otherwise available so as to get them into usable form.

3. To induce the general adoption of a standardized heat transmission research objective to the end that all new research will be conducted in such a way that it will yield generally valuable information.

It is proposed that a suitable committee be organized under the auspices of the National Research Council and the work divided among six sub-committees, namely, publicity; bibliography; theory, nomenclature and definitions; temperature measurements; heat transmission of insulating and building materials, and heat transmission between fluids and solids.

The first work proposed is the critical review of material already published which could be considered in the light of an audit. It is proposed that each article be properly classified, and the material in it abstracted and rearranged in accordance with an approved outline. Critical comments bringing out conclusions in addition to or at variance with the authors will be kept in mind. It is proposed that the full time services of a competent engineer be engaged in this work under the direction of the committee.

Need for Investigations

Heat transmission is in an unsatisfactory state. There is the greatest need for quantitative information that can safely be generalized, for coördination of present knowledge, and for coördination of future work. The nature of this work is executive, editorial and advisory. The establishment of a research laboratory is not contemplated and full use will be made of all present research facilities. The aim is to make present knowledge available in its most usable form, to direct attention to specific items wherein present knowledge fails us, to indicate how future investigations may rectify these faults, and, finally, through publicity, to encourage heat transmission research in accordance with the standards set by the proposed committee on Heat Transmission.

BUREAU OF STANDARDS NOTES

Factors Affecting the Resistance of Tank Block to Glass Attack

Probably one of the most annoying sources of trouble to manufacturers of commercial glass on a large scale is the lining of the glass melting tanks. Very frequently these linings fail through corrosion after 10 to 14 months' service which results in a considerable loss of time and money. A life of 20 to 24 months for such a lining is not considered an unreasonable service to expect. Since the need for better tank refractories is so generally felt the Bureau has deter-

mined to conduct an investigation covering the various typical brands now used to determine, if possible, the relation between refractory composition, conditions of service and life. In order to get the investigation under way 27 small tanks have been made using refractories which are typical of dense and open burned aluminous and siliceous brands, as well as brands of medium composition. These will be subjected to the corrosive action of a soda-lime glass at high temperatures and the reactions obtained will be correlated, if possible, with the various types of refractories used.

A Study of the Factors Affecting the Life of Boiler Setting Refractories

The need has been felt for a long time of a better test covering the resistance of boiler setting refractories to slagging. Although the investigations which the Bureau has carried out on refractories for the development of specifications have shown that the service can be predicted with fair accuracy from the results of certain tests, it seems desirable to develop a laboratory slag test in order that factors of composition, both of the slag and refractory and their comparative effect on the life of brick, may be determined. The apparatus necessary for carrying out such a test has been designed and constructed and it is proposed to observe the effect of high, medium and low fusing clinker on various brands of refractories. Test panels of the brick to be investigated will be brought to a high temperature by means of a blast impinging on the brick. Finely ground and artificially prepared clinker will be introduced into the flame and in this way brought into contact with the test panel.

STANDARDIZATION, THE BULWARK OF STRENGTH AND PROGRESS OF INDUSTRIES IN GERMANY

Standardization of industrial production has been one of the important factors in enabling Germany to maintain its industrial machine intact, in the face of the multitude of obstacles now confronting that country.

"The extent to which Germany has so far succeeded in keeping her industrial machine intact, is due in no small part to the elaborate scale on which her standardization work is performed," it is stated by Dr. P. G. Agnew, Secretary of the American Engineering Standards Committee, who recently returned from Europe, where for two months he made a study of the standardization movement and the manner in which European developments in this direction are likely to affect American industry.

"The elaborateness of the organization for the work, its activity, and the scale on which it is being carried out constitute a new development in industrial organization.

"Practically every important manufacturing concern in Germany is officially participating in the industrial standardization program of that country. More than a thousand German companies have formal standardization organizations within their own works. These organizations are called 'standards bureaus.' The larger firms have branch bureaus in the separate departments, or in the separate factories. One of the well known companies has twenty-one such branch bureaus, employing in all a special staff of more than one hundred. Another firm has a permanent full-time staff of over two hundred in its various branch bureaus. In all of the great firms the bureau reports directly to the general manager."

The extent to which industrial life in Germany has been coördinated, it is stated, is shown by the fact that more than seven hundred German national standards have been adopted. This includes only those in which several different industries are concerned, and which are approved by the central national body. These include fundamental engineering standards as: standard diameters, tapers, sizes of keys, threads,

fits, etc.; materials, tools, measuring instruments and gages, machine parts, including handles, ball and journal bearings, etc.; gears, and sizes of paper.

In addition to this work of the central body, and closely correlated with it are no less than sixty-five special industry committees actively working on such subjects as: the standardization of pipe fittings, piping, and accessories, welding, steel construction, concrete and reinforced concrete, fire fighting equipment, windows, doors and stairways, foundry practice, the printing trades, merchant marine, locomotives, motor trucks, laboratory apparatus, photographic supplies, non-ferrous metals, precision tools, sand, gravel and street paving material, typewriters, highway bridges, rolling mills, and railway car construction.

A striking example is cited of the efficiency of national standardization as it has been developed in Germany, in the case of a rush order placed with German manufacturers for 200 locomotives for delivery to Russia. "Production of different parts was allotted to seventeen different manufacturers to be produced strictly upon the plan of interchangeable parts, no one manufacturer making a complete locomotive. No serious practical difficulty was encountered in filling the order. The inspectors made a particularly striking test of the feasibility and accuracy of the plan by ordering a complete locomotive to be assembled from parts chosen at random from the parts furnished by the seventeen manufacturers. It proved to be ready for service immediately after assembly without the necessity of any disassembling for readjustment.

Standardization engineering is now a recognized profession in Germany. The rapid development of standardization organizations within the companies has made a large demand for such work. Advertisements for standardization engineers and for such positions regularly appear in the engineering press.

An interesting development of the last few years is the appearance of consulting engineering firms specializing in standardization work. There are now five such firms in Germany. This work is closely connected with industrial or efficiency engineering, in which there is now great and growing interest in Germany. In general, it appears to be much more closely connected with the movement for industrial standardization than is the case in this country. The largest of these firms devotes about half of its time to standardization work, employing a staff of over forty. They have as their clients trade associations as well as individual firms, the latter including both large and small companies.

One of their clients is the trade association representing the motor vehicle industry. In this work they perform many of the services that would be done by an ordinary headquarters standardization staff.

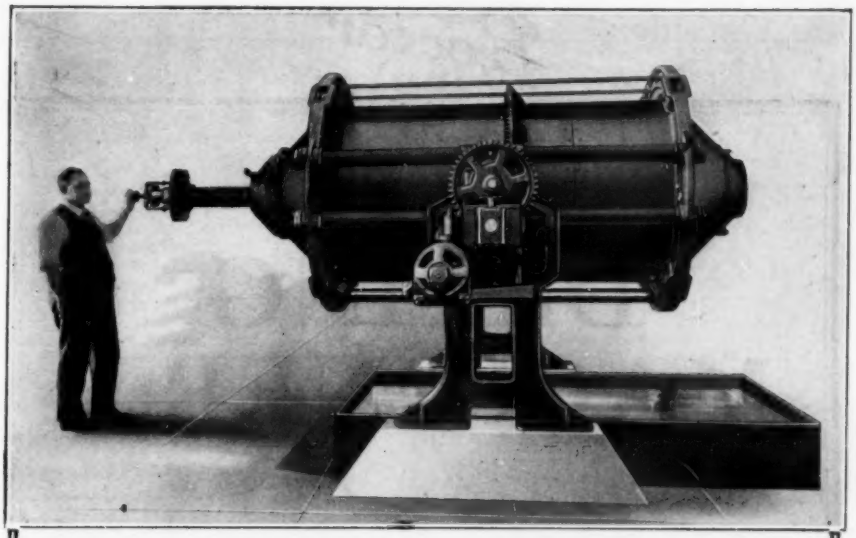
Of the companies which are their clients, some maintain their own standards bureaus, which take care of the greater part of the detailed work, leaving to the consulting firm only the more important and difficult questions. In other cases, the consulting firm does a large amount of the detailed work.

Another most interesting development is the work of consulting engineers on trade catalogs for companies. This is particularly significant, as it is carrying standardization a step farther than is usual, by introducing it into the sales organization and sales policy. In this, careful consideration is given to the question of limiting the number of types, ranges and sizes offered for sale, placing proper emphasis in the catalog on these particular items on which the company wishes to concentrate, and, in general, in featuring and often advertising the relation of the firm's products to the standardization movement.

CALENDAR OF CONVENTIONS[1]

Organization	Date	Place
AMERICAN CERAMIC SOCIETY (Annual Meeting)	Feb. 4–9, 1924	Atlantic City
(Summer Meeting)	July 21–Aug. 16, 1924	Trip to Pacific Coast
American Concrete Institute	Feb. 25–28, 1924	Chicago
American Institute of Electrical Engineers	Feb. 4–7, 1924	Philadelphia
American Zinc Institute	May, 1924	St. Louis, Mo.
Assn. of Scientific Apparatus Makers of U. S. A.	April 18, 1924	Washington, D. C.
Common Brick Mfrs. Assn. of America	Feb. 11, 1924	Los Angeles, Calif.
Institute of Metals, Div. of American Institute of Mining and Metallurgical Engineers	Feb., 1924	New York City
Natl. Assn. of Stove Mfrs.	May 7–8, 1924	New York, Hotel Astor
Natl. Bottle Mfrs. Assn.	April 27, 1924	Atlantic City
Natl. Brick Mfrs. Assn.	Jan. 28–Feb. 2, 1924	Cincinnati, Ohio
Natl. Builders Supply Assn., Inc.	Feb. 11, 12, 1924	St. Louis, Mo.
Natl. Electric Light Assn.	May or June, 1924	
Penna. Gas Assn.	April, 1924	Atlantic City
Society of Promotion Engineering Education	July, 1924	Boulder, Colo.
Stoker Mfrs. Assn.	April or May, 1924	(?)
Western Society of Engineers	June 4, 1924	Chicago

[1] Further information may be secured through the Chamber of Commerce of U. S., Washington, and World's Convention Dates, New York, N. Y.



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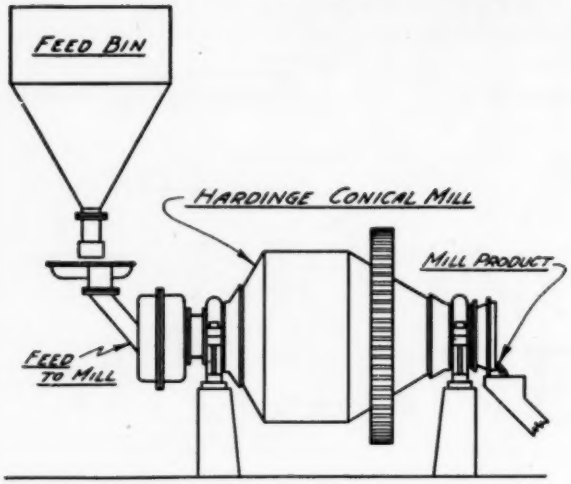

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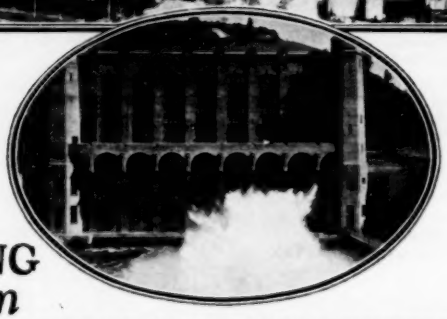

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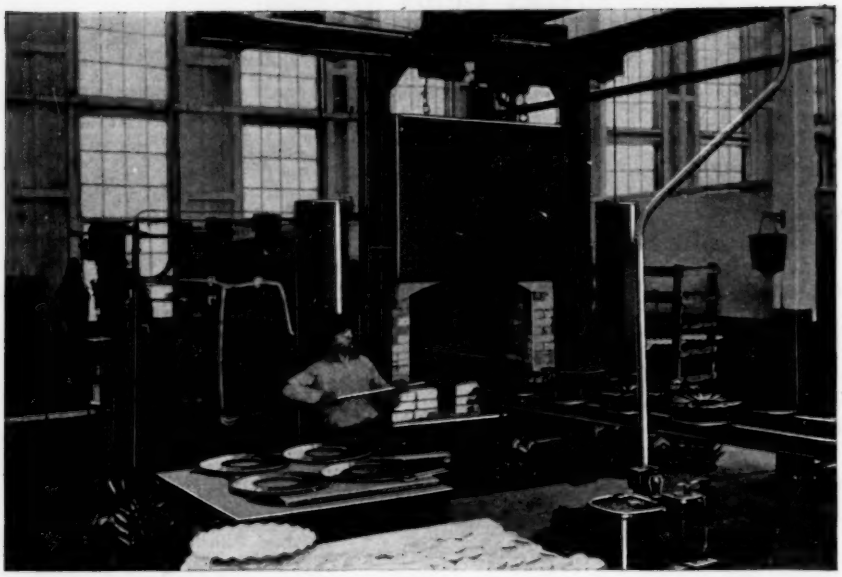

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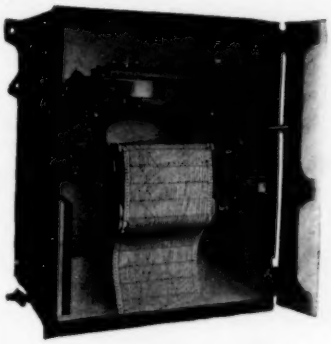

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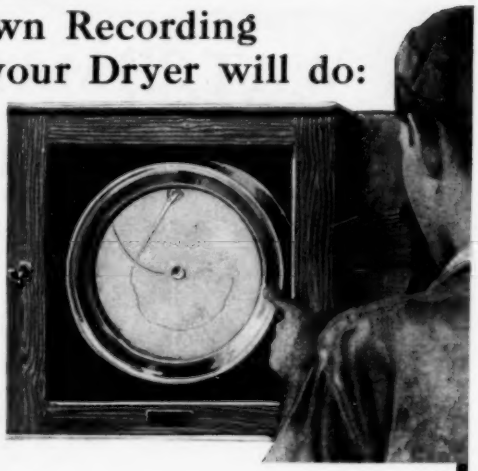

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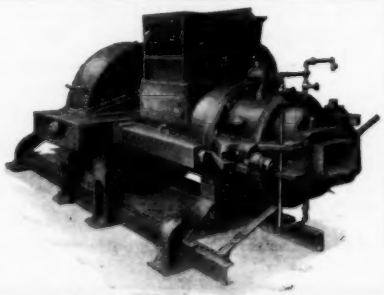

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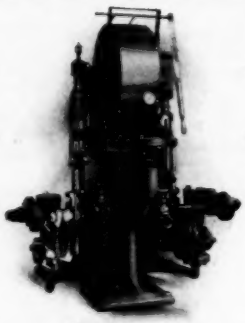

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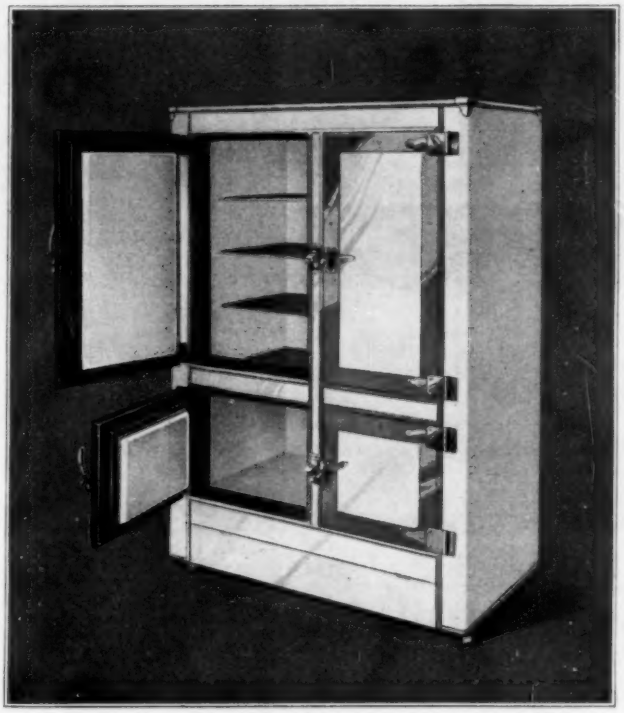

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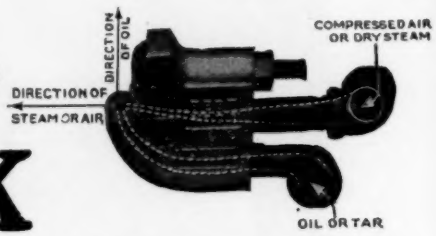

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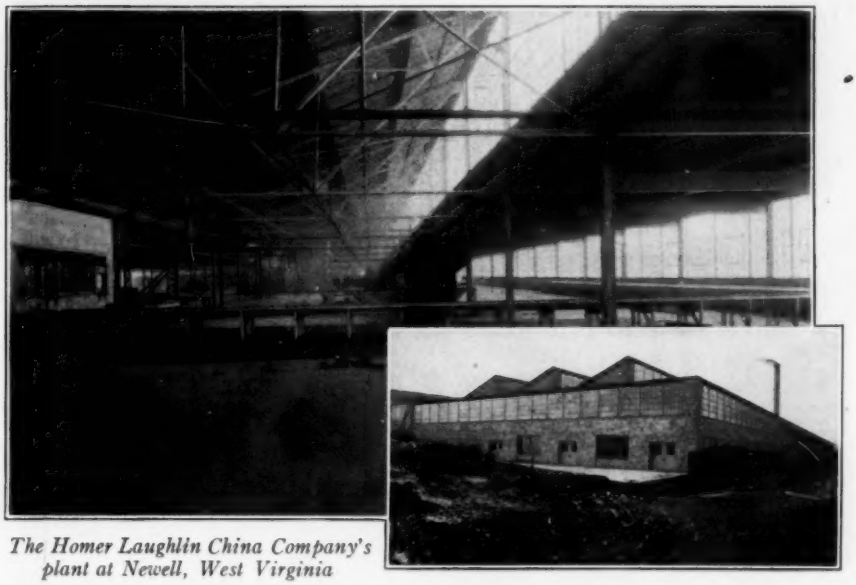

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